COMBUSTION

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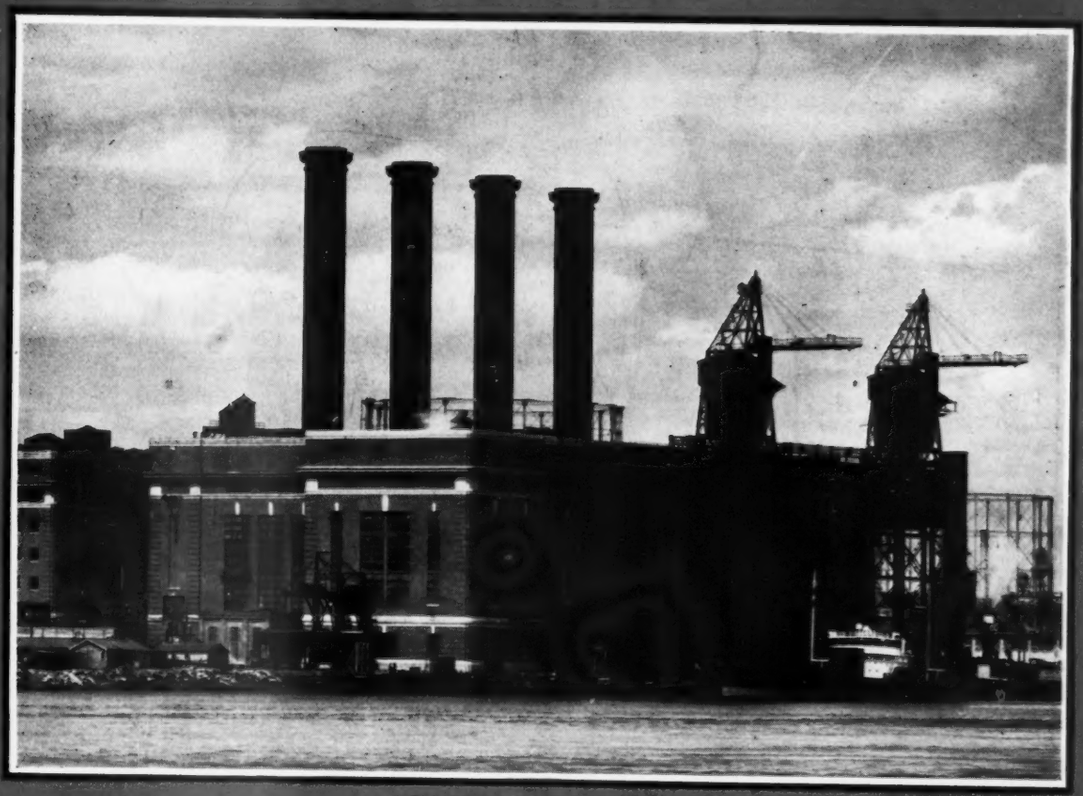


HELL GATE STATION, UNITED ELECTRIC LIGHT AND POWER COMPANY

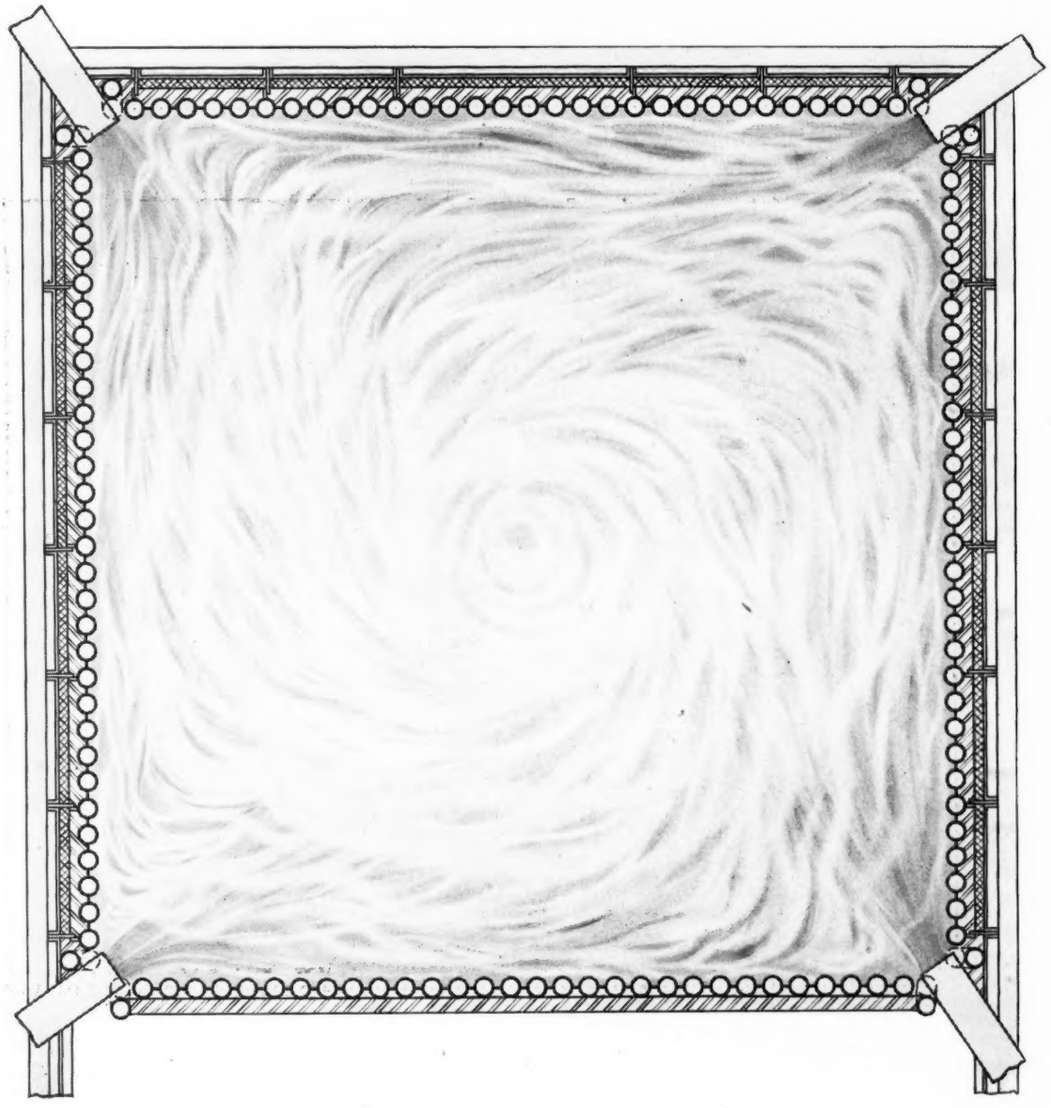
Heat and the First Law of Thermodynamics
By WM. L. DEBAUFRE

Determination of the Dust Content of Gases
By W. A. GROBLI

Progress in the Use of High Pressure Steam
By J. B. CRANE

OTHER ARTICLES IN THIS ISSUE BY
A. A. MARKSON • DAVID BROWNLIE • B. J. CROSS

HORIZONTAL TANGENTIAL FIRING



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COMBUSTION

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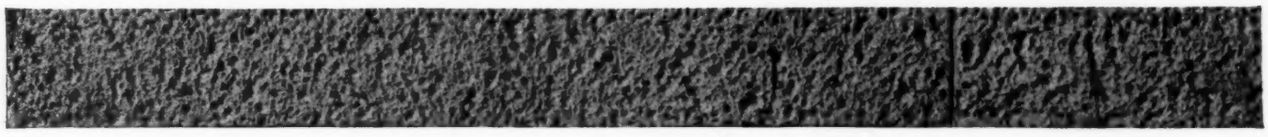
Sized Brick Make Tight Jobs



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Vol. 1 April 1930 No. 10

PROGRESS—1920 to 1930

Underwood

JULIUS KLEIN

THE more we examine the technical and commercial progress of American industry during the past decade, the more impressive the facts become. Every index in every industry furnishes evidence of progress that is truly startling, and the progress in the combustion field is no exception to this rule. Including fuel burned on railways and for residential heating, as well as fuel consumed in central stations and for factory power, there is reason to believe that the efficiency of combustion of all sorts has increased perhaps thirty per cent during the past decade. Three tons of coal now do the work formerly done by four on the broad average.

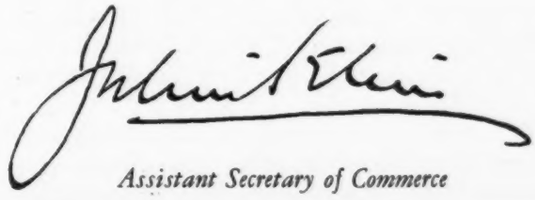
In particular lines much greater progress has been made. The consumption of coal per kilowatt hour by electric central stations was reduced forty-five per cent in the interval between 1919 and 1928. The consumption of locomotive fuel per thousand gross ton miles declined twenty-six per cent between 1917 and 1927. The consumption of coking coal per ton of pig iron declined twelve per cent between 1919 and 1926, and in this connection mention should also be made of the recovery of by-products in the coke industry which formerly were wasted. The proportion of coke made in "by-product" ovens rose from eighty-seven per cent for 1916 to 1920 average, to ninety-two per cent in 1928.

A recent statement from British sources provides evidence of the progress made in the design of steam turbines, the weight of which per kilowatt having fallen from 42.5 pounds in 1918 to 13.9 pounds in 1929, the capacity of the largest units having increased during that interval from 25,000 to 60,000 kilowatts, and the efficiency has also been raised by some thirty-eight per cent. These figures are perhaps more or less representative of conditions in the United States also, although we have some units of over 100,000 kilowatt capacity.

In particular instances results have been secured which represent a very marked advance over the broad averages mentioned which apply to the field as an entirety, but in particular instances the application of powdered fuel, water-jacketed furnaces, high steam pressures and superheats, even mercury vapor, furnish substantial evidence of the extreme care which engineers are devoting to the problem of extracting every possible heat unit or every possible kilowatt from each pound of coal, and there are plants that deliver a kilowatt for less than a pound of coal.

But, just as Dr. Jekyll in Stevenson's thrilling story was inseparably involved with the unfortunate personality of Mr. Hyde, we should perhaps remember that progress has a similar ugly sister in the form of obsolescence. The greater the progress the more serious the obsolescence factor becomes, because this factor can invisibly liquidate the assets of an enterprize unless guarded against with the greatest care. A western manufacturer recently published a magazine article under the title, "The Terrible Costs of Obsolescence." This impressed me as an unfortunate form of expression because what he was really describing was "The Terrible Costs of Progress."

Whenever foreseen, adequate obsolescence losses can be provided for in exactly the same manner as one would meet any other business cost, and through the establishment and maintenance of appropriate reserves, managers can prepare themselves for the day when replacement becomes necessary.



Assistant Secretary of Commerce

EDITORIAL

Opposite View-Points—Both Correct

IN THE design of steam boiler furnaces, the pendulum of concepts has swung from one extreme to the other.

Fifteen years ago an intensive campaign was being carried on to increase the height of boiler settings in order to get the "cooling effect" of the boiler tubes away from the fuel bed.

Horizontal water tube boilers were raised from the old standard settings of six or seven feet, to ten, twelve, fifteen and as much as twenty feet from floor line to header.

Today, an equally vigorous campaign is being waged to extend the use of all-metal water-cooled furnaces. In modern practice the boiler is practically built around the furnace so as to expose the maximum amount of heat absorbing surface to the burning fuel.

In certain furnaces of this type, it has been found that the greater part of the heat absorption is by radiation and that a comparatively small percentage of the heat is transferred by convection.

To the casual observer, there would appear to be two conflicting schools of thought represented,—the first demanding that the heat absorbing surfaces be removed from the fire as far as practicable, and the second contending that the heat absorbing surfaces be brought as close to the fire as practicable.

The answer to this paradox is, that both are correct.

The fundamental requisites for the complete combustion of coal in air are briefly, contact, time and temperature.

With hand firing, or certain types of stokers and simple furnaces, high settings are required to provide combustion space which will give sufficient opportunity for each particle of volatile matter distilled from the coal, to seek out and combine with the air before the gases reach the boiler tubes where the temperatures are below the ignition point.

The exponents of high settings can present innumerable tests to prove that increasing the distance from fuel bed to boiler, raised the operating efficiencies, permitted higher overload capacities and eliminated smoke. For their particular conditions of firing and furnace design, they have proved the wisdom of taking the boiler "out of the fire."

In modern practice, with turbulent firing of pulverized coal, intimate contact of fuel and air is secured directly in front of the burners. This thorough mixing and the tremendous surface area of pulverized coal exposed to air, insure practically instantaneous combustion of the volatile matter, with a minimum of excess air required, and high furnace temperatures.

The size of the furnace is determined by the time necessary to burn the fixed carbon so as to reduce the unburned carbon loss to a reasonable value. As the furnace walls play no part in supporting combustion, they may comprise steam generating surface so designed as to secure the maximum absorption of heat from the burning fuel by radiation, thereby reducing furnace temperatures and consequently reducing the tendency of the ash to slag.

This condition is most favorable to the all-metal water-cooled furnace, which is recognized as the logical answer to the first fundamental law of steam generator design,—*Get the heat out of the fuel and into the water as quickly and as directly as possible.*

The operating records of all-metal furnaces show tremendous rates of heat transfer, high operating efficiencies and the ability to burn a fuel as lean as washed blast furnace gas with no ignition difficulty.

The present trend is unquestionably toward the all-metal water-cooled furnace, in order to expose the maximum amount of heat absorbing surface to the radiation effect of the combustion gases.

Two schools of thought, apparently conflicting, but each correct for its particular fuels and firing methods.

Throttling Legislation Threatened

BY the killing of a bill in Committee, the steam power and heating plants of New York State have again escaped threatened drastic supervision under state politics.

The bill recently introduced before the State Legislature aimed to create a division of steam power and heating plants in the Department of Labor. A code, applicable to both existing and future plants, was to be prepared for the installation, alteration and equipping of steam plants.

Thus, under the Labor Law and in the guise of a safety measure, impractical restrictions on the steam plants of the state were threatened. The issue was local. However, if the measure had been enacted in New York State, it would have served as a precedent for other states.

Such legislation smacks of bureaucratic government of a type which may present endless opportunity for bickering, delay, waste, petty politics—and worse.

Every plant owner, builder and operator should be on the alert to recognize and defeat the adoption of insidious measures which fall in this category.

Heat and the First Law of Thermodynamics

By WM. L. DE BAUFRE*
International Combustion Engineering Corporation, New York

IT IS a familiar fact that when two bodies at different temperatures are brought into intimate contact, they both eventually come to the same temperature. We say that heat has been transferred from the body of higher temperature to the body of lower temperature. The correct theory of the phenomena involved in the addition or abstraction of heat from a body has been developed only within the past one hundred years. These phenomena will be discussed in the present article.

With this article, Mr. DeBaufre concludes the first group of his series on Engineering Thermodynamics. Previous articles in the series have been devoted to fundamental mechanical units and to temperature scales. In the present article the author deals with the subject of heat and its relation to temperature and mechanical units. Subsequent articles will consider the thermal properties of fluids, expansion and compression of fluids, flow of fluids, and the conversion of heat into mechanical work.

The Mechanical Theory of Heat

In the early days of the study of heat phenomena, it was thought that heat was a material fluid called "caloric." A rise in temperature was believed to be due to absorption of caloric fluid while cooling was due to abstraction of this fluid from a body. Transfer of heat from one body to another was supposed to correspond to the passage of caloric fluid from the warmer to the cooler body. When a substance passed from the solid to the liquid state or from the liquid to the gaseous state, it was observed by Joseph Black in 1761 that a large amount of heat was absorbed without a corresponding rise of temperature. Since the absorption of heat in such cases did not produce a rise in temperature, the caloric fluid was said by Black to become "latent." We thus have the latent "heat of fusion" absorbed by a substance in changing from a solid to a liquid, and the "latent heat of evaporation" absorbed in changing from a liquid to a vapor, in contradistinction to "sensible heat" which produces a change in temperature only of the body to which it is imparted.

The caloric theory of heat, however, failed to explain satisfactorily the production of heat by friction or the changes in temperature accompanying the compression and expansion of gases. In 1798, Rumford became interested in the heat produced during the boring of cannon. It was previously supposed that caloric fluid was set free in breaking up metal into small particles. By using a blunt boring tool, Rumford produced a very large amount of heat during the removal of a very small amount of metal. As the supply of heat appeared inexhaustible, he concluded that heat could not be a material substance but must be something in the nature of motion. In 1799, Davy described an experiment in which he melted ice by rubbing together two blocks of ice. Since water was known to contain more heat than ice, the heat produced by friction evidently did not come from the internal heat of the blocks of ice. Many additional physical facts, particularly regarding the properties of gases, had to be brought to light, however, before the caloric theory was generally displaced about 40 years later by the mechanical theory of heat.

According to the mechanical theory, heat is a form of energy. The generation of a given quantity of heat corresponds to the disappearance of a certain amount of mechanical or other form of energy; and, conversely, when a certain amount of mechanical work is performed by a heat engine, an equivalent quantity of heat must disappear. This fact has been designated as the first law of thermodynamics. The mechanical theory of heat was first placed upon a sound experimental basis by Joule who began experimenting upon the relations between various forms of energy in 1840.

The Unit of Heat

If a ten-gram piece of copper at a temperature of 500 centigrade were dropped into 100 grams of water at 20 centigrade, a final temperature of 24.6 centigrade would be reached if no heat were lost to the surroundings. This shows that copper has a heat capacity of

$$\frac{100\,(24.6 - 20)}{10\,(500 - 24.6)} = 0.097$$

as compared with that of water. By similar methods, Black, Rumford and others compared the heat capacities of many substances with that of water as a standard. The unit of heat accordingly came to be defined as the quantity of heat required to raise unit weight of water through one degree of temperature. Although the units of weight and of temperature have been definitely specified as explained in preceding articles, the unit of heat will remain somewhat indefinite until universal agreement is reached as to the exact temperature of the water at which the one degree change in temperature is to take place.

The unit of heat in the metric system has been named the calorie and is sometimes designated as the gram-calorie or the kilogram-calorie to indicate whether the gram or the kilogram is taken as the

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mass of water heated through one degree centigrade. The temperature change has been variously taken as 0 to one degree, at the temperature of maximum water density (4 degrees centigrade), at 15, 18 and 20 centigrade, or as the mean value from zero to 100 centigrade. In the English system of units, the unit of heat is the amount of heat required to raise the temperature of one pound of water one degree fahrenheit, and this unit is called the British thermal unit, generally abbreviated to B.t.u. in speaking of it as well as in writing it. Another heat unit occasionally used is the heat required to raise the temperature of one pound of water one degree centigrade, designated as the centigrade heat unit (c.h.u.) or the pound-calorie. We will define the several heat units as follows:

The (mean) kilogram calorie is one hundredth of the amount of heat required to raise the temperature of one kilogram of water from zero to 100 centigrade under normal atmospheric pressure.

The (mean) B.t.u. is 1/180 of the amount of heat required to raise the temperature of one pound of water from 32 to 212 fahrenheit.

The (mean) c.h.u. is 1/100 of the amount of heat required to raise the temperature of one pound of water from 0 to 100 centigrade.

The Mechanical Equivalent of Heat

From the experiments by Joule published in 1849 on the relations between different forms of energy, the mechanical equivalent of heat, often called Joule's equivalent and represented by J, was for many years taken as 772 ft-lb. per B.t.u. Based upon the experiments of Rowland in 1880, of Griffiths in 1893, of Shuster and Gannon in 1895, of Reynolds and Moorby in 1897 and of Callendar and Barnes in 1897 and 1899, the mechanical equivalent of heat may now be taken nearly one per cent higher. The latest determination made in 1927 at the U. S. Bureau of Standards of the relation between the heat capacity of water between its normal freezing and boiling points and the electrical unit of energy gave

One mean gram calorie = 4.189 joules (absolute)

Corresponding values in other units are

One mean kg-cal. = 427.2 kg-m.
One mean B.t.u. = 778.6 ft-lb.
One mean c.h.u. = 1401.5 ft-lb.

At the International Steam Table Conference held in London in July, 1929, it was decided to adopt for recording the total heat of steam, the international kilo-calorie defined as the heat equivalent of an international kilowatt-hour divided by 860. This is equivalent to

One International Calorie
= 4.186 International Joules.

The international kilowatt-hour is an electrical unit based on internationally accepted concrete standards for the ohm and the ampere. The standard for the ohm is the electrical resistance of a column of mercury of specified dimensions at the temperature of melting ice. The standard for the ampere is a certain rate of deposition of silver from a solution of silver nitrate under specified conditions. These concrete electrical standards have been so chosen as to make the international electrical units nearly identical with the absolute system of units based on the centimeter, the gram and the second. There is, however, a slight discrepancy so that

One International Joule = 1.00034 absolute joules.

This discrepancy makes

One International Calorie = 4.1875 absolute joules

which is less than the latest determination of the mean calorie as given above.

The advantage of basing the unit of heat upon electrical units lies in the fact that the thermal properties of substances are generally measured calorimetrically either directly or indirectly in terms of electrical energy due to the convenience in making precise electrical measurements. The action of the International Steam Table Conference in selecting a definite conversion factor between heat and electrical units has been heralded as the passing of the mechanical equivalent of heat. As long, however, as the thermal properties of substances are given in terms of a heat unit, a "mechanical equivalent" must be used for the ratio between this heat unit and the unit employed for expressing mechanical work done.

We will now state the first law of thermodynamics in simpler form than heretofore given:

Heat and mechanical work are different forms of energy, and when one form is converted into the other, the ratio is 778.6 ft-lb. to one B.t.u.

Internal Energy and External Work

One of the most notable effects of the addition of heat to a body is its expansion, which may take place even against considerable resistance. Thus, long steam pipes firmly anchored to columns when cold, have been known to push the columns out of place by expansion when warmed by steam passing through them. In overcoming such external forces, mechanical work is done and an equivalent amount of heat energy must disappear.

Let us assume that the body receiving a small quantity of heat dq changes its volume an amount dv against an external pressure p. If no heat passes out of the body otherwise than through the performance of mechanical work p dv, there must, according to the first law of thermodynamics, be an increase du in its internal energy equal to dq minus A p dv, where A is the reciprocal of the mechanical equivalent of heat. That is,

$$dq = du + A\,p\,dv$$

This is a mathematical expression for the first law of thermodynamics as applied to the heating of any body, and it states that the heat added to a

body is equal to the increase in internal energy plus the external work done.

As an example of the above relation, consider the evaporation of water in a boiler while the steam space is in communication with an engine cylinder, the piston of which is actuating the plunger of a water pump as indicated in Fig. 1. If the steam pressure remains constant, it is apparent that the piston displacement must exactly equal the increase in volume of water as it is evaporated into steam within the boiler, the steam in the pipe connecting boiler and engine simply serving for the time being as a pressure transmitting medium. The evaporation of water within the boiler therefore accomplishes the mechanical work of moving the engine piston which in turn actuates the pump plunger and thereby raises a given weight of water through a certain height. The increase in potential energy of the water raised and the work of overcoming all frictional resistances to movement of the water raised, of the pump and engine parts and of the steam within the pipe connecting boiler and engine, comes from the heat added to the water in the boiler. Under a steam pressure of 70 lb. gage, 84.7 lb. per sq. in. absolute, the volume of one pound of steam from the Steam Tables of J. H. Keenan, is 5.181 cu. ft. while the volume of one pound of water is 0.018 cu. ft. Hence the external work of changing one pound of water into steam is equivalent to

$$\frac{144 \times 84.7\ (5.181 - 0.018)}{778.6} = 80.9 \text{ B.t.u.}$$

It has been found by experiment, however, that the generation of one pound of steam under the above conditions requires 897.5 B.t.u., the latent heat of evaporation as given in the Steam Tables above mentioned. Consequently, the increase in internal energy must be 897.5 — 80.9 = 816.6 B.t.u. per lb. That is, the addition of 897.5 B.t.u. to one pound of water to evaporate it into steam under 84.7 lb. per sq. in absolute, increases the internal energy 816.6 B.t.u. and performs external work equivalent to 80.9 B.t.u. The internal energy remains in the steam—the external work is energy transmitted to surrounding bodies.

Internal Kinetic and Potential Energy

An understanding of the accepted explanation of the manner in which internal heat energy exists in bodies is helpful in applying thermodynamics to engineering problems. Internal heat energy is considered to exist as kinetic and potential energy of the smallest particles, or molecules, of the body. The molecules of all bodies are considered to be continually in motion and the kinetic energy due to this motion is sensible heat. A change in temperature thus corresponds to a variation in kinetic energy of the molecules due to a change in the rapidity of their motions. Also, the molecules of a body are believed to be mutually attracted one to another so that expansion of a body with addition of heat means that potential energy is stored up in increasing the distances between the molecules. Such additions of heat become latent. An increase in latent heat is also found, at times, when no increase in volume occurs. For example, when ice at 32 fahr. is converted into water by the addition of 143.5 B.t.u. per lb. with no change in temperature, the volume actually decreases as evidenced by the fact that ice floats on water. In this case, there must be a storing up of internal potential energy not associated with an increase in volume but due to some changes in arrangements of the molecules.

For liquids, vapors and gases, such changes in arrangements of the molecules are generally associated directly with increases in volume or in temperature, as when a liquid changes to a vapor or when dissociation occurs in gases at high temperatures. For fluids, the internal energy in a given mass may therefore be said to depend upon the

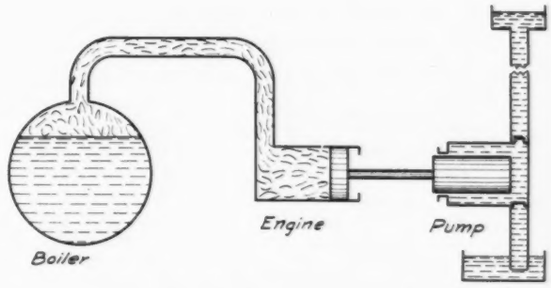


Fig. 1—Evaporation of water into steam and external work done thereby

temperature T and the volume v only. In the language of mathematics, u is a function of T and v, that is,

$$u = f(T, v)$$

By differentiation,

$$du = \left(\frac{\partial u}{\partial T}\right)_v dT + \left(\frac{\partial u}{\partial v}\right)_T dv$$

That is, a change in internal energy of fluids is in general equal to the rate of internal energy change with temperature at constant volume times the change in temperature plus the rate of internal energy change with volume at constant temperature times the change in volume. The first term $\left(\frac{\partial u}{\partial T}\right)_v dT$ is the change in kinetic energy of the molecules, or the sensible heat, the second term $\left(\frac{\partial u}{\partial v}\right)_T dv$ is the change in potential energy of the molecules, or the internal latent heat.

Substituting the above value of du in the preceeding equation for the heat dq added to a body, we obtain

$$dq = \left(\frac{\partial u}{\partial T}\right)_v dT + \left(\frac{\partial u}{\partial v}\right)_T dv + Ap\,dv$$

This expression is a mathematical statement of the fact that the addition of heat to a fluid produces one or more of the three following effects:

(a) Raises the temperature of the fluid by increasing the kinetic energy of the molecules—this is sensible heat.

(b) Expands the fluid against mutual attractions of the molecules, thereby increasing the internal potential energy—this is internal latent heat.

(c) Expands the fluid against external pressure—this is external latent heat. The energy corresponding to the external latent heat passes out of the fluid to surrounding bodies where it is usefully applied in raising water, cutting or forming metal, generating electricity, etc., or is dissipated as heat produced in overcoming frictional resistances.

Specific Heat of Solids and Liquids

The specific heat of any substance is the number of units of heat required to raise unit weight of the substance through one degree of temperature

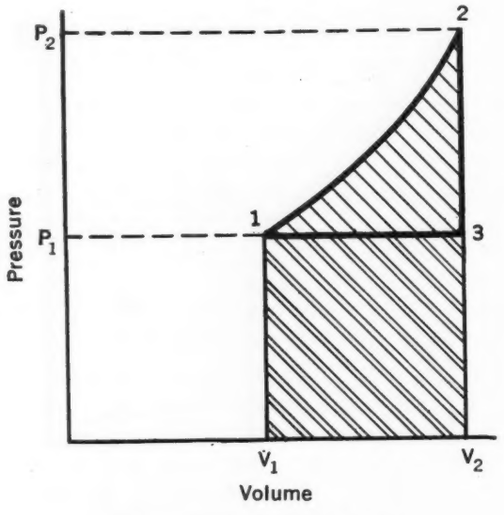


Fig. 2—External work diagram

change. Specific heat is therefore measured in B.t.u. per lb. per deg. fahr. or in cal. per kg. per deg. cent. The heat Q B.t.u. absorbed by W lb. of a substance in heating it from t_1 fahr. to t_2 fahr., is given by

$$Q = W \int_{t_1}^{t_2} c\,dt$$

where c is the specific heat in B.t.u. per lb. per degree fahr. at temperature t fahr., sometimes called the instantaneous specific heat to distinguish it from the mean specific heat over a range in temperature. In many engineering problems, the specific heat of solids and liquids may be taken as constant over a wide range of temperature. In other instances, however, such an assumption would not give sufficiently accurate results and it becomes necessary to regard the specific heat as a function of the temperature according to some such relation as

$$c = a + b(t-32) + e(t-32)^2 + \text{etc.}$$

where c is the specific heat at t fahr., a is the specific heat at the melting point of ice and b, e, etc., are constants. Often, the conditions are represented sufficiently accurately by

$$c = a + b(t-32)$$

With the centigrade temperature scale, the specific heat c is usually measured in gm. cal. per gm. (or kg. cal. per kg.) per deg. cent.; but when the centigrade heat unit is employed, the specific heat is in c.h.u. per lb. per deg. cent. The expression for the specific heat as a function of temperature on the centigrade temperature scale is

$$c = a + bt + et^2 + \text{etc.}$$

or more simply

$$c = a + bt.$$

Substituting this value of c in the expression for the heat Q cal. (or c.h.u.) added to W gm. (or lb.) of material to raise its temperature from t_1 to t_2 cent., we have

$$Q = W \int_{t_1}^{t_2} (a+bt)\,dt$$

$$= W\left[a\,(t_2-t_1) + \frac{b}{2}(t_2^2-t_1^2)\right]$$

$$= W\left[a + \frac{b}{2}(t_2+t_1)\right](t_2-t_1)$$

If we denote the mean specific heat between t_1 and t_2 cent. by c_m cal. per gm. per deg. cent., we have

$$Q = W\,c_m(t_2-t_1)$$

whence

$$c_m = a + \frac{b}{2}(t_2+t_1)$$

The numerical values of a, b, e, etc., are independent of the units of mass employed provided, of course, that the weight of the body heated or cooled is expressed in terms of the same unit of mass as that used in the unit of heat. The numerical value of a is also independent of the temperature scale employed provided the change in temperature of the body heated or cooled is given in the same scale as that used in the unit of heat. The numerical value of b for the fahrenheit scale, however, is 5/9 of the value for the centigrade scale, and the numerical value of each of the constants in the succeeding terms for the fahrenheit scale is equal to the value for the centigrade scale multiplied by the same power of 5/9 as the power of the temperature in the term in question. That is, the products bt, et^2, etc., must have the same numerical values irrespective of the temperature scale employed so that the calculated specific heats at certain actual temperatures will be the same irrespective of the temperature scales used.

Specific Heat of Gases and Vapors

Although the expansion of solids and liquids with change in temperature may be of great practical

importance, the external work corresponding to the expansion is only a very small portion of the heat added. With gases and vapors, however, a comparatively large increase in volume occurs when heated under constant pressure, so that an appreciable portion of the heat added is converted into external work. If heated with constant volume, the pressure of the gas or vapor being permitted to increase with rise in temperature, no external work is performed. Consequently, the specific heat at constant volume is appreciably less than the specific heat at constant pressure. Either of these two specific heats may be considered as a function of temperature and the heat added to the gas or vapor calculated as described for solids and liquids.

If, however, a gas or vapor expands or contracts during the addition of heat with neither pressure nor volume constant, the calculation of the heat added becomes more complicated.

Total Heat, or Heat Content

On adding heat to any substance, we have seen that part of this heat remains within the substance as an increase in its internal energy while another part passes out of the substance as the external work done. This fact is represented by

$$dq = du + A\ p\ dv$$

where dq is the heat added, du is the increase in internal energy and A p dv is the external work done. The change in internal energy du depends only upon the initial and final conditions of the substance. The external work done may be represented on a pressure-volume diagram as in Fig. 2. The area under the curve connecting points 1 and 2 represents the external work performed when the pressure is gradually increased from P_1 to P_2 while the volume increases from V_1 to V_2 during the heating of a fluid from temperature t_1 to temperature t_2. Integrating the above mathematical expression, we obtain for the heat added,

$$\Delta q = (u_2 - u_1) + A \int_{V_1}^{V_2} p\ dv$$

$$= (u_2 - u_1) + A[\text{area } 12\ V_2\ V_1]$$

Instead of the pressure and volume varying according to curve 12, suppose that we had first heated the fluid in question at constant pressure to point 3 and then at constant volume until point 2 was finally reached. The internal energy change would have been the same because the initial and final conditions of the fluid would have been the same. The external work, however, would have been less as represented by the smaller area 13 V_2 V_1. The heat added under this supposition would have been

$$\Delta q = (u_2 - u_1) + A[\text{area } 13\ V_2\ V_1]$$

This quantity of heat is less than that required under the first supposition by reason of the difference in the external work done.

Since the amount of external work depends upon every intermediate pressure and volume as well as upon the initial and final conditions of the fluid receiving heat, it is evident that the quantity of heat added likewise depends upon the way in which the pressure varies with the volume. It is therefore necessary to specify completely the conditions under which heat is added to a substance in order to have a perfectly determinate quantity.

The total heat, or heat content, of unit weight of a substance at a certain temperature and pressure is

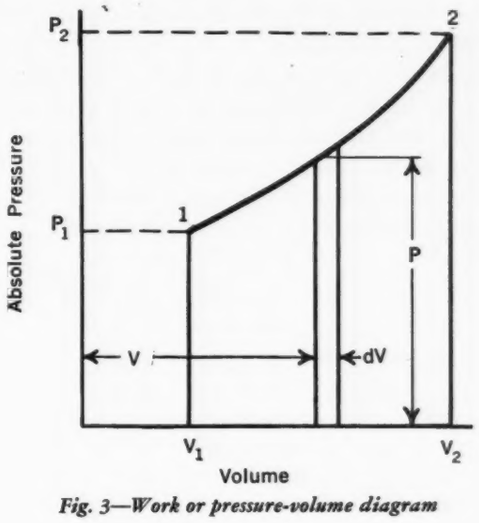


Fig. 3—Work or pressure-volume diagram

thus meaningless unless the method of determining it is arbitrarily agreed upon. The terms "total heat" and "heat content" originated when heat was considered to be a material fluid and it was believed that under specified conditions a substance would always contain the same total quantity of this fluid. Under the mechanical theory of heat, total heat and heat content, sometimes called "enthalpy," is now defined by the mathematical expression

$$h = u + A\ pv$$

in order to have a determinate quantity. In tables of the thermal properties of fluids, it is customary to give the total heat above some convenient reference temperature such as the melting point of ice. We should therefore write

$$h = (u - u_0) + A\ pv$$

where u_0 is the internal energy at the reference temperature. At the reference temperature, however, A pv is not zero so that the total heat is not zero at this temperature. In accordance with this mathematical expression, the total heat of a substance may be defined as the internal energy above that at the reference temperature plus the heat equivalent of the product of its pressure and volume. This definite quantity is particularly useful in calculations concerned with constant pressure changes such as ordinarily occur in the generation and condensation of steam in power plants. Unless the pressure remains nearly constant, however, it is necessary to apply the more general relation

$$dq = du + A\ p\ dv$$

utilizing experimentally determined values of the

internal energy at the initial and final conditions and calculating the external work from the actual pressure volume relations involved. If the internal energy is not given in the tables of the thermal properties of the substance under consideration, it may be calculated by substracting from the tabulated values of the total heat the corresponding values of A pv.

The Heat, or Temperature-Entropy, Diagram

The external work performed during the addition of heat to a substance is very conveniently represented, as indicated in the preceding paragraphs, by a diagram having as co-ordinates the volume of the substance and the absolute pressure supported by it. The area under the curve indicating the variation in pressure, represents the external work done by the substance during expansion or done upon the substance during compression. For a very small change in volume dV as shown on Fig. 3, we have the work done

$$dW = P\,dV$$

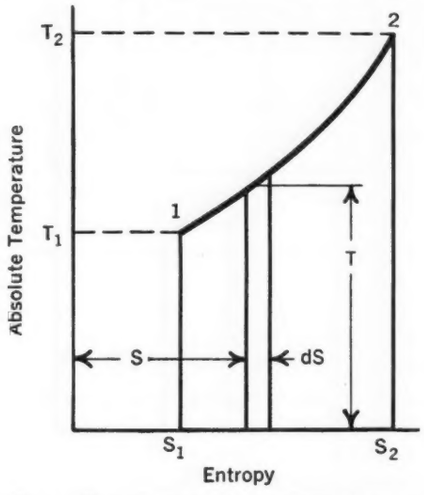


Fig. 4—Heat or temperature-entropy diagram

The total work done from point 1 to point 2, represented by the area under the curve 12 in Fig. 3, is given by

$$W = \int_{V_1}^{V_2} P\,dV$$

In order to represent on a diagram in a similar manner the heat added to the substance as its temperature changes, it is necessary to have another quantity such that the product of the absolute temperature T by a small change in this quantity ds will equal the heat added dq; that is,

$$dq = T\,ds$$

The total heat added between absolute temperatures T_1 and T_2 is then represented by the area under the curve 12 in Fig. 4 and is given mathematically by

$$\Delta q = \int_{T_1}^{T_2} T\,ds$$

This quantity s has been named the entropy of the substance and its significance will be discussed in future articles. For present purposes, it is sufficient to define it by the mathematical relation

$$ds = \frac{dq}{T}$$

The change in entropy between absolute temperatures T_1 and T_2 is given by

$$s_2 - s_1 = \int_{T_1}^{T_2} \frac{dq}{T}$$

Since the heat added to a substance between temperatures T_1 and T_2 depends upon all intermediate values of its pressure and volume which determine the external work done, the change in entropy between T_1 and T_2 must also depend upon the pressure-volume relation. In tables of the thermal properties of steam and other substances, the entropy is generally given above some fixed temperature such as that of melting ice. In order to have a determinate value of the entropy of a substance above a fixed temperature, it is necessary to specify the pressure-volume relation during the heating. The heating is accordingly considered as occurring with the substance subjected to a pressure equal to that of its saturated vapor at the temperature of the substance at each instant.

It may be noted that the total heat and the entropy are thus not consistent quantities in that the total heat is based on a constant pressure while the entropy is based on a variable pressure. Since the total heat h is defined by

$$h = (u - u_0) + A\,pv$$

we have

$$dh = du + A\,d(pv)$$
$$= du + A\,p\,dv + A\,v\,dp$$

now $dq = du + A\,p\,dv$

Therefore, $dq = dh - A\,v\,dp$

The relation between entropy and total heat is accordingly given by

$$ds = \frac{dq}{T} = \frac{dh - A\,v\,dp}{T}$$

References

Preston's Theory of Heat will be found of interest by the reader who desires to go more fully into the study of this subject than was possible in the present article. The various experimental means used to determine the mechanical equivalent of heat will be found described in Preston's book and also in the article entitled "Heat, mechanical equivalent of," in Glazebrook's Dictionary of Physics. The latest determination at the U. S. Bureau of Standards of the "Mechanical Equivalent of the Mean Heat Unit," is given under "Progress in Steam Research" in Mechanical Engineering for February, 1928. The action of the International Steam Table Conference in July, 1929, with regard to this quantity is described in Mechanical Engineering for February, 1930. In this issue also appears the article entitled, "The Passing of the Mechanical Equivalent of Heat."

Development of a High Pressure System for Boiler Water Conditioning

By A. A. MARKSON
Mechanical Engineer, New York Steam Corporation, New York

THE purpose of any system of boiler water conditioning is to maintain such conditions in the boiler water that the production of steam will not cause the formation of deposits on the heating surfaces. If in the accomplishment of the primary object, secondary difficulties develop, these latter must be eliminated without interfering with the accomplishment of the main objective. At Kips Bay Station of the New York Steam Corporation, the Hall System of boiler water conditioning by means of phosphate was found to be extremely satisfactory in the elimination of deposit from the heating surfaces, but in its original application secondary difficulties either existed or arose, which had to be traced down and eliminated. These difficulties were as follows:

1. The boilers produced wet steam.
2. Heavy deposits formed in the economizers.
3. It was not possible to maintain low alkalinities in the boiler water while maintaining economizer corrosion protection.

The author describes the high pressure system of boiler water conditioning, using the Hall phosphate treatment, as developed at the Kip's Bay Station of the New York Steam Corporation and later installed at Station A, operated by the same company. The theoretical aspects of the work are fully discussed, and the equipment and operation described in some detail. Definite conclusions are offered based on observations extending over a period of nearly twelve months. This paper, which was presented at a recent meeting of the Metropolitan Section of the A. S. M. E., is a valuable contribution to the literature on this important subject.

The problem of wet steam at Kips Bay, and its solution, has been fully discussed in a paper by A. R. Mumford, Boilers and Furnaces, published in Vol. 51, No. 22, of the A. S. M. E. Transactions. Study of this problem developed the following facts:

(a) that there was a critical value of the concentration of boiler caustic alkalinity, above which it was practically impossible to accomplish the mechanical removal of entrained moisture, and below which mechanical purification was entirely practicable.

(b) that the concentration of other dissolved substances and suspended matters had a negligible influence on the quality of steam delivered from the boilers, within the concentration ranges covered in the experiments.

The caustic concentration was kept below the critical value by increasing the blowdown, until its control by chemical means could be effected. The sources of the caustic were two: that added to inhibit the economizer corrosion, and that formed by the break-down of the carbonates in the boiler water. Some caustic alkalinity is necessary in the boiler water to insure the maintenance of conditions called for by the Hall system for the formation of non-adherent precipitates. Obviously the economizers would be subjected to accelerated corrosion by the elimination of the caustic added to the feed water. Furthermore, the presence of carbonates in the make-up insured a constantly increasing concentration of caustic soda in the boiler water.

Because of the fact that no deposits formed in the economizers before the Hall system was adopted it was rather obvious that the adding of conditioning chemical directly to the boiler would eliminate completely the zones unfavorable to conditioning by the Hall system. By using a less alkaline sodium phosphate than was previously employed advantage could also be taken of the possibilities of keeping the boiler alkalinity under control by partial neutralization in the boiler, rather than by excessive blowdown.

The author has noted considerable interest on the subject of economizer and feed line scale deposition, as evidenced by several recent contributions on the subject, both experimental and speculative in nature.

One theory advanced seems to hold that the product formed when phosphate is added to the feed water is in a supersaturated condition until it hits the heat absorbing surface, at which point equilibrium is suddenly induced by the sharp change of temperature. The product carried along in a state of supersaturation then precipitates. Another hypothesis developed to explain the formation of deposits where none should occur, is that there is a film effect at the heating surfaces in which film precipitation occurs. Based on the experiences we have had with our economizers and feed lines at both Stations A and Kips Bay, we advance a theory which differs from those mentioned.

It is our opinion that there is much to be learned as to the exact physico-chemical nature of substances in solution. Our economizers scaled up very heavily, and the deposits were by no means limited to the tubes, but seemed, if anything, to be worse

*Abstract of paper presented at a meeting of the Metropolitan Section of the A. S. M. E., February 3, 1930.

in the headers and on the plugs. This point was enough to question the specific validity of the supersaturation and film theories for these conditions. It is the writer's belief that the answer to the question of such depositions will be found in the existence of products which are more basic in nature than those which are conventionally supposed. These products, of which there may be several, may have the general formula

$$(Ca)\ w\ (OH) \times (PO_4)\ y\ (H_2O)\ z.$$

instead of being straight calcium phosphates. Some of the experimental facts in support of this contention are weak, but they may be summarized as follows:

(1) If the boiler water environment is not kept at a causticity *materially greater* than that theoretically required to insure tricalcic phosphate, adherent deposits form.

(2) If a sample of boiler water is allowed to stand without being filtered and the clear liquid above the sludge is analyzed on successive days, the concentration of phosphate in the clear liquid will be found to increase, apparently due to the slow action of caustic soda on the calcium phosphate.

(3) At the time the high pressure system was first put into operation at Kips Bay, it so happened that on two boilers the internal feed lines terminated in open-ended pipes above the upcomers. It was noticed when these boilers were taken off the line for inspection thirty days after the system had been in operation that there were well defined circular patches, under the feed line discharge pipes which were of the same composition as the material which was formerly deposited in the economizers.

The writer believed at the time of the inspection that the cause of these patches was that the incoming feed water had no chance to mix with the boiler water to more than a slight extent thus resulting in a solution weak in phosphate and alkali being directly localized under the feed pipes. If this theory were true it would follow, so it seemed, that securing a uniform distribution of feed water in the drum would not merely spread the deposit over a greater area, but should actually cause such deposition to disappear. This proved to be true.

To recapitulate, the cause of the economizer and feed line scale depositon is essentially due to the maintenance of lower alkalinity in the feed water

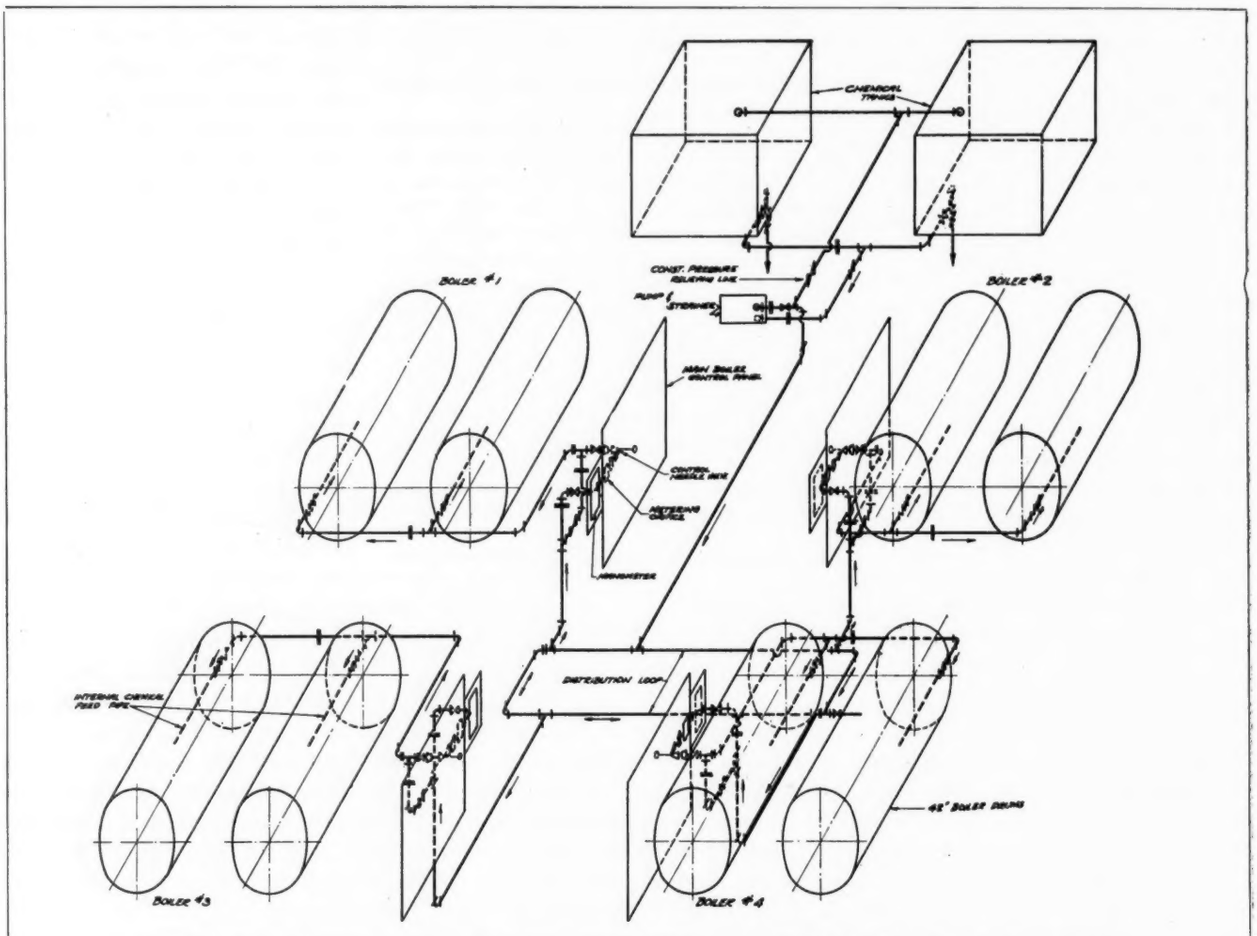


Fig. 1—Schematic arrangement of boiler water conditioning system installed at the Kips Bay Station of the New York Steam Corporation

than is required to prevent the formation of non-adherent precipitates. This required alkalinity is in excess of 100 parts per million of OH, five-fold higher than the maximum we could economically add because of the resultant high blowdown required.

Deveolpment of the H. P. System

In developing the system which was installed at Kips Bay, and later at Station A, certain mechanical conditions were set forth which must be met by the general scheme. In the first place, any such system ought to be simple to operate, to adjust, and to maintain. Secondly, the amount of special attendance necessary for the functioning of such a system ought to be a minimum. Third, the system ought to be under complete and accurate control at all times, with visible and positive indication of its functioning.

It is believed that the system which is to be described met these requirements very well. The general simplicity of the design is evidenced by the fact that both the installed systems have shown no fundamental defects in ten months of operation at Kips Bay Station and five months at Station A.

The principle of the system may be thus briefly described: if a chemical charge of calculated strength be fed into the boilers in exact proportion to either the feed water entering the boilers or the steam generated by the boilers, the optimum condition for internal treatment of boiler water will be attained. The assumption that the amount of treatment is proportional to the steam generated is probably true for most cases. The system accomplishes this in the following manner. A high pressure pump maintains a constant head of chemical solution in the distribution loop. Feeds to individual boilers are taken off this loop. A metering orifice is placed in each boiler chemical line and the flow from the loop into the individual boiler is manually controlled by means of a needle valve placed after the metering orifice. The metering orifice indicates the flow of chemical by means of a graduated manometer which is under the observation of the boiler operator. The manometer scale is graduated to correspond with the boiler meter flow reading. The operator, therefore, has merely to adjust the control needle valve until the correct indication is obtained on the manometer, at which time treatment requirements will be satisfied.

The system is composed of the following component parts, shown schematically in Fig. 1:

(a) Supply tank
(b) Suction strainer
(c) High pressure pump with constant head by-pass.
(d) Main feed loop
(e) Metering orifices
(f) Control needle valves
(g) Indicating manometers
(h) Distribution pipe in boiler

We shall first discuss the design of the metering and control system.

The Orifice

In the design of the orifices for use in metering the chemical, the limiting factors are the available supply tank capacity, the number of boilers to which it is desired to apply the system and the question of probable accuracy obtainable in metering small quantities. There is a limit of minimum flow below which metering difficulties, such as the use of orifice plates having microscopic holes, are apt to appear. Furthermore, since the total amount of solution fed into the system depends to a large extent on the number of boilers in the station, it follows that the chemcial solution tanks will have to be larger

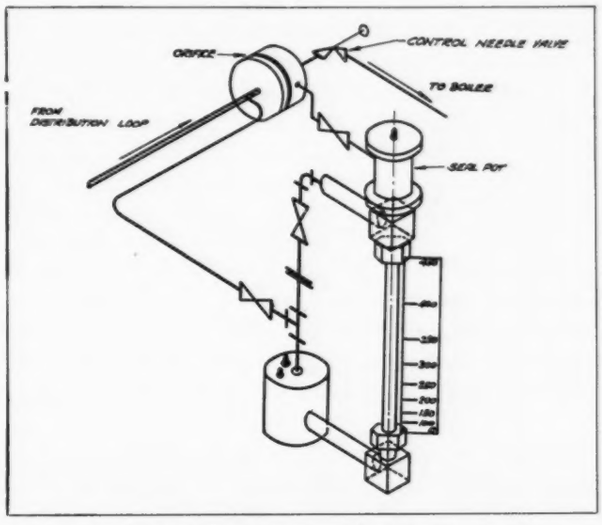


Fig. 2—Indicating device used at Kips Bay Station

in capacity as the number of boilers goes up, in order that the tanks may not empty in too short a time. Where the number of boilers is relatively large, as in Station A where there are now 14 boilers, a single large tank may be used and a very small auxiliary tank employed to feed the system while the large tank is out of service for recharging. The tanks are equipped with air agitation so that outage is minimized.

At Kips Bay Station there were two 7000-gal. tanks available for holding the chemical charge. The maximum daily load on the Station at that time was about 24,000,000 lb. Feeding from alternate tanks, it was desirable that recharging intervals should not be shorter than 48 hours at the maximum station load. This means that the average hourly feed would be 7000 divided by 48, or about 145 gal. per hr., which corresponds to an average hourly steam generation of 1,000,000 lb. per hr. It was therefore necessary to feed chemical at the rate of 2.4 gal. per min. for an hourly evaporative rate of 1,000,000 lb. As the maximum load per boiler is somewhat over 400,000 lb. per hr., the figure which was used in designing the metering system

was one gallon per minute chemical flow when the steam flow meter indicated 400,000 lb. per hr. generation.

We used in our installation an 0.365 orifice plate. The differential corresponding to a flow of one gallon per minute is about four inches of water, depending somewhat on the density of the chemical solution. Carbon tetrachloride was selected as the gage liquid and was colored a brilliant red by the use of "pylol" red, a dye which is insoluble in water.

The Indicating Device

The design of the indicating device will now be discussed. It is shown in Fig. 2. As may be seen, it is nothing more than a high pressure cistern manometer of somewhat special construction. Attention may be directed to the fact that it uses a ¾ in. standard boiler gage glass and has a cup on the top combination which acts as a safety seal pot. The writer understands that the Merriam Co. of Cleveland furnishes a very acceptable line of such manometers. At least one other manufacturer makes a very neat manometer which has a pointer indicator.

The Control Valve

As shown in Fig. 3, the control valve is placed at the manometer, so that the operator's duty consists of maintaining the manometer reading at the scale point corresponding to the reading of either his feed water or steam meter in a manner analogous

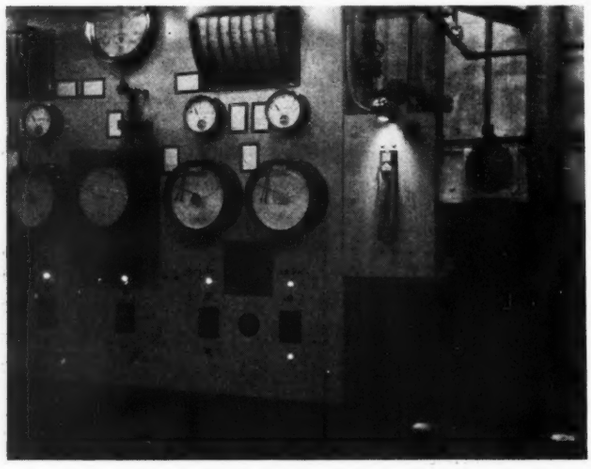


Fig. 3—Control panel. Manometer and control valve are shown on small board at right

to controlling the air flow pen on the boiler meter. The control valve should be placed after the orifice for obvious reasons. For the control valves we have found that ¼ in. Vogt steel needle valves function perfectly under our conditions.

The Loop

In designing the loop a maximum velocity should be chosen which tends to make the loop act as a pressure reservoir. One or two feet a second is satisfactory. Welded joints are preferable, although we have had no trouble with screwed or flanged pipe on this service at our pressure (400 lb.). Check valves should be employed where necessary, and all valves and fittings ought to be of iron or steel and of the best quality obtainable

The Pump

The pump, as might be expected, is the point in the system upon which success depends. The first one which was selected was a small Triplex pump, and while its functioning was never such as to threaten the success of the system, we felt in selecting a change-over pump that the Triplex could be considerably improved upon. We have therefore installed a Waterous rotary pump. This pump works on a rotor displacement principle and is directly driven by a slow speed motor. The ideal pump is a centrifugal, but these are apparently not made in very high head and low enough capacities. If a pump of tremendous excess capacity is used it will be entirely too wasteful of power.

Triplex pumps, if enough care is taken in selection, should be good for pressures up to about 600 lb. Rotary pumps, however, are only good for pressures up to 350 lb., but may be staged in series to give any desired working pressure. They are the cheapest and simplest form of pump for the service.

Constant Pressure Relief

A spring loaded relief valve is used to by-pass the excess of fluid pumped back to the supply tanks and to maintain a fairly constant head on the discharge loop. The constancy of this head is very important, in order that the control needle valve will not require readjustment at constant rating. We were unable to buy a suitable all-iron valve for the service, but we found that a standard bronze valve, when chromium plated, was satisfactory. If a pump is selected of ample capacity, a durable needle valve may be used instead of a loaded relief valve.

In the operation of the system the pump pressure should be set at a point which will insure a negligible effect of variations of boiler pressure on the flow through the boiler control needle valve. For example, if the boiler pressure varies five pounds from the usual operating point it will only affect the indication of the manometer very slightly when a drop of 100 lb. is induced across the control valve but rather seriously if the drop induced across the control valve is in the neighborhood of only 10 lb.

The suction strainer is a duplex strainer of our own making, having strainer baskets of 40-mesh monel cloth. The assembly is arranged so that a strainer can be cleaned in about ten minutes without interrupting the service.

Conclusion

In conclusion, the advantages of a high pressure system such as the one described are

(*Continued on page 34*)

Determination of the Dust Content of Gases

By W. A. GROBLI
Dust Recovery, Inc., New York

IN THE past two years, innumerable articles have been written relative to the dust content of gases. In some cases methods are offered for determining this dust content, while in others the ridiculous statement is made that no satisfactory methods have been developed for this determination.

Years ago John Aitken devised means for counting the number of dust particles in the atmosphere even though such particles were beyond the range of the most powerful microscope. A discussion of this need not be given here for its application is primarily for the scientist. In commercial fields, the problems created are not due to this ultra-fine atmospheric dust, but are due to such artificial dusts as can be screened and examined under the microscope, and simpler methods of test are available which are accurate enough for all practical purposes.

The elimination of dust, together with other obnoxious elements from stack gases, is becoming an essential consideration in connection with stations located in centers of population. A complete and satisfactory solution of this problem, which will conform to reasonable economic requirements, has not yet been reached. Rapid progress is being made in this direction and developments are being watched with marked interest. The author of this article considers only the methods of determining the dust content of flue gases, and describes one particular method which is recommended because of its accuracy, simplicity and relatively low cost.

Coupled with the dust content of gases is the question of determining the operating efficiency of dust collectors. Here again, absurd statements have been made to the effect that the collector efficiency can not be determined because the dust content of the gases treated can not be established.

Experiments by the leading manufacturers of dust collecting equipment and by purchasers of such equipment in certain branches of industry have definitely proven to the satisfaction of all concerned that tests of this nature may be run and an accuracy established within 3 per cent. As far as industry or public health bureaus are concerned, this degree of accuracy gives everything that is required.

While in this article the dust resulting from the combustion of powdered coal and commonly termed "Fly Ash" is dealt with, the method of test and data outlined herein can readily be applied in testing the dust content of gases in other industries such as cement, gypsum, metallurgical, etc., without material change.

Various terms are employed to convey an idea as to the amount of dust present in stack gases. We speak of the "dust concentration," the "dust loading of the gas," the "gas loading" or simply the "loading," which term is generally understood and acceptable. To express this loading accurately and quantitatively, the cubic foot is used as the unit of gas volume and the grain (avoirdupois) as the convenient unit of dust weight. Thus, we may, in a certain case, have a dust loading of two grains per cubic foot of gas.

Changes in temperature or pressure do not, in the average commercial application, affect the weight of dust in stack gases, but they do greatly alter the actual gas volume. For this reason, the dust loading must be further defined by giving the corresponding temperature and pressure. This may be for standard conditions of temperature and pressure or for the actual operating conditions. The latter is perhaps preferable as it gives a better picture of the actual dust loading of the gas.

Several methods for determining the dust loading of gases in a flue or stack have been developed. Invariably, a sample of the dust laden gas is extracted from the main flue and the dust in this sample separated by means of filtering or washing. The net weight of dust is thus determined and by dividing this weight by the volume of gas extracted, the dust loading is established.

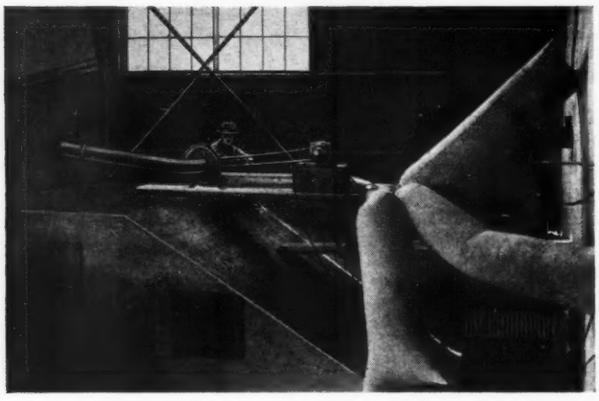
Of the various means employed for conducting this test, most of them handle only a small volume of gas, that is, two to ten cubic feet per minute. Accordingly, all measurements must be made with extreme accuracy, otherwise, erroneous results will be obtained. Furthermore, there is a real possibility that such a small sample will not represent true average conditions as they exist in the main flue, and the data thus obtained may readily be misleading.

One method greatly reduces this possibility of error due to the fact that a comparatively large gas volume is analyzed. This method is known as the "bag test," and, as the apparatus required is simple and inexpensive, the method of conducting the test and the calculation and application of the results will be described. Reference is here made to the sketch shown on page 33.

Let us assume a flue carrying the gases of combustion from a powdered coal fired boiler. At some point in this flue, near the end of as long a straight run as possible, a sampling duct is inserted as indicated. This duct, for average conditions, may be 4 in. or 6 in. in diameter and constructed of light gage metal with the seams soldered to prevent leakage.

The outer end of the duct connects to a small fan or blower driven by an electric motor provided with a variable speed control so that the volume and velocity of the gas in the duct may be regulated.

The fan outlet is provided with a duct, damper and manifold as indicated to which heavy muslin or canton flannel bags are attached. These bags can be made of 8 oz. material. If canton flannel is used, the bags should be made with the nap on the inside. A convenient size of bag is 2 ft. diameter by 12 ft.



Photograph showing set-up of bag test apparatus

long, which can readily be made by taking a piece of 72 in. by 12 ft. material, and after folding lengthwise, running a double stitch along the side and one end.

The number of such bags employed will depend upon the volume of gas per minute to be filtered. By maintaining a filtering area of one sq. ft. of bag area for three cu. ft. per minute of gas, a good filtering condition will result. Thus, with a test apparatus handling approximately 1,000 cu. ft. per minute five bags of the size mentioned will be satisfactory.

In the use of filter bags as above described, the question may arise as to the possible loss of dust through the mesh of the fabric. Assuming that the bags are in good condition, this loss will be entirely negligible and will consist almost entirely of the natural atmospheric dust which is revealed only under the most powerful microscope. In some cases a slight haze may be noticed when a test is first started and when new bags are used but the dust in the gas soon collects in the mesh and forms its own filtering medium so that the escaping gas appears entirely clear. Under these conditions, the efficiency of the bags has been determined as being 99.4 per cent.

All gas measurements are made with Pitot tubes, as this is the most accurate method available where the gas quantity is large. Much has been said about the proper method of handling the Pitot tube to obtain the most accurate readings.

Technically speaking, the proper way is to accurately divide the flue, either round, square, or rectangular, into several parts of equal area and then take readings in the center of each of these areas. The average will then give an approximation of the average for the total area. This method is undoubtedly the most accurate provided the walls of the flue are clean and there is no eddying or banking of the gas stream. In most installations, however, this condition arises and it has therefore been found that in actual practice it is always advisable to thoroughly explore the full cross sectional area of the flue by taking a large number of preliminary readings over the full area and from these establish the individual characteristics of the gas flow at each point. It is then possible to plot out the results and establish one or more points, depending upon the size of the flue at which future readings may be taken. With a little study and practice, the problem may be handled with confidence.

The actual use of the Pitot is generally understood, but certain precautions are of course necessary. The velocity opening must always face the gas flow squarely. Care should be taken that the static holes are clear and particularly where the tube is used in connection with gases containing considerable moisture care must be observed that condensation does not occur and plug up the static holes. This condition can generally be overcome by heating the tube just before placing in the gas stream.

It is advisable to use a good grade of manometer, at least 12 in. long and accurately calibrated. Where the velocities are low, it is advantageous to place this manometer at an inclination of five to one in order to get more accurate readings, and where the velocities are very low, an inclination of ten to one should be used. Experience has proven that the best liquid to use in the manometer is benzine colored with alkanette or some other readily soluble dye of brilliant hue. This liquid is very active, is susceptible to the slightest variation in pressure and will not gum or get sluggish. Being colored a bright red by the alkanette, it is easily read. The specific gravity of this liquid should be obtained so as to permit conversion to water readings and it should also be noted that corrections must be made for whatever inclination is used. All readings should be reduced to and stated as "inches of water." In the use of the Pitot, the gas temperature is a most important factor and accordingly, thermometer readings must be taken near the point where the Pitot is used.

Having obtained the velocity head of the gas by means of the Pitot tube and manometer and also the temperature, the gas velocity in the flue at the point of measurement may be obtained from formulae or charts. The inside dimensions of the flue at the point where Pitot readings are taken must also be obtained and the product of the sectional area and the gas velocity naturally gives the gas volume flowing through the main flue.

It will be noted from the sketch that the entrance to the test duct is made in the shape of an expanding

bell. The reason for this is that while the same gas velocity must be obtained at the entrance to this bell as exists in the main flue, the gas velocity in the test duct should be approximately 5,000 ft. per minute in order to prevent dust settling in this duct. In order to illustrate the importance of having the correct gas velocity at the entrance to the bell, the conditions surrounding this point will be described.

If the gas velocity in the main flue is higher than the gas velocity entering the test duct, the dust loading in the test duct will be higher than in the main flue. This is due to the fact that there will be banking of the gases at that point with the result that a considerable portion of the dust carried in the higher velocity gas will be projected into the slower moving stream thereby increasing the dust loading at that point.

If the opposite condition exists, namely, a lower gas velocity in the main flue than at the entrance to the test duct, the dust loading in this duct will be lower than in the main flue. This is due to the fact that a suction will be created at the duct entrance which induces the gas in over the edges of the intake, while a large portion of the dust particles,due to their initial velocity and heavier weight, will be projected past these edges and carried along in the main gas stream.

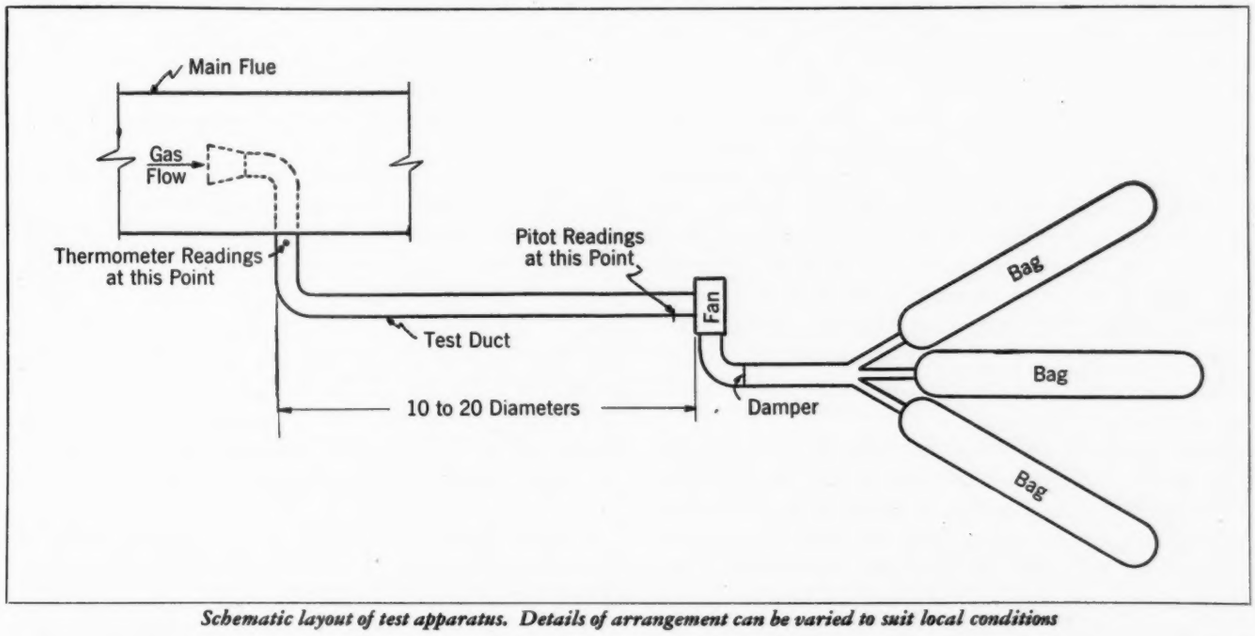
Therefore, if the gas velocity is the same in the flue and at the entrance to the test duct, the gas and dust flow will be undisturbed with the result that the gas sample withdrawn through the test duct has the same dust loading as the gas in the main flue.

Assuming a gas velocity of 2,200 ft. per minute in the main flue and a test duct diameter of 4 in. a simple calculation will show that if the expanding bell is 6 in. in diameter at entrance, proper conditions will be obtained if the volume through the test duct is 432 c.f.m. and the velocity 4,950 f.p.m. For other conditions the bell will have other proportions while the diameter of the test duct will depend upon the volume of gas it is desired to analyze.

The sampling tube or duct is provided with a small opening to take Pitot readings so that the actual gas velocity and volume through the duct can be determined. In order that uniform conditions will be obtained, the readings in this duct should be taken at a point near the end of a long straight run equal to at least ten diameters and preferably twenty diameters of the duct.

With the actual gas velocity in the main flue determined and the proper velocity through the duct calculated, the fan and damper are adjusted until the correct velocity is obtained in the duct.

The location and position of the test duct in the main gas stream is of great importance. The entrance to the bell must always face the gas flow squarely. It will also be found necessary to run several preliminary tests in order to determine that location which represents the average dust loading in the main flue. This location will generally be below the center of a horizontal run of flue for the reason that the dust concentration increases near the bottom due to settlement.



Schematic layout of test apparatus. Details of arrangement can be varied to suit local conditions

Having established all conditions and set up the entire test apparatus so as to obtain true average results, the actual test or tests may be started.

The test, under proper conditions, may be run from one to six hours, depending upon the total gas volume it is desired to analyze and upon the dust loading of the gases. Where it is known that the loading is heavy, a comparatively short test will generally be sufficient, whereas under light dust loadings a longer test is necessary in order to secure

more accurate readings. If at all possible, all conditions should be held constant during the entire period of the test. If this is impossible, then simultaneous readings should be taken at intervals of fifteen minutes during the entire testing period. Due to the fact that conditions are certain to vary to some extent, even though the attempt is made to hold them constant, it can be stated that it is always advisable to take a series of readings at 15 minute intervals and use the average result in making final calculations.

With reference to the bags, the only precaution which should be taken, outside of the fact that they must be in good condition, is to see that they are dry. If this is the case, the bags and contents are weighed before and after each test and the difference in weight then represents the amount of dust trapped during the period of the test. Very often, however, moisture precipitates in the bags due to condensation from warm gas, while if the bags are initially damp, they become dried because of warm gas. Under these conditions, the net weight of dust trapped can not be determined with any degree of accuracy by simply weighing. In this case, it is essential that the bags and contents be dried before and after each test and before weighing.

From the readings taken during the test, we can calculate the gas volume passed through the bags. If the weight of dust trapped is divided by this volume, the quotient represents the dust loading of the gas through the test duct. This must correspond with the dust loading in the main flue provided the test has been run in the proper manner and provided the temperature in the duct is the same as the temperature in the main flue. If there is an appreciable temperature difference between these points, then it must be compensated for in order to obtain the true dust loading of the gases in the main flue. As previously stated, this dust loading can best be expressed in grains avoirdupois per cubic foot of gas.

If the dust loading is multiplied by the gas volume in the main flue, we at once obtain the total weight of dust being carried during a given period of time. Very often this dust is of value so that its recovery represents a direct financial return. In other cases, a certain percentage of this dust must be eliminated in order to prevent or eliminate complaints due to its settlement in the vicinity.

In the case where dust collectors are installed, the dust loading of the gas offers a simple means of determining their efficiency . The dust loading of the gas before entering and after leaving the collector is determined on the basis of equal gas temperatures at these two points. The difference in loading represents the loading trapped by the collector. This difference divided by the loading entering the collector and multiplied by 100 gives the collector efficiency in per cent.

As a check, the dust trapped by the collector may be weighed and reduced to a corresponding dust loading and this loading divided by the loading at entrance and multiplied by 100.

In conclusion, one further advantage of the bag test may be mentioned. Large representative dust samples are obtained which can be screened for fineness and further examined for shape, density and other characteristics. The information thus gained is invaluable in the selection of suitable dust collectors.

Development of a High Pressure System for Boiler Water Conditioning

(*Continued from page 30*)

(1) It solves the question of economizer deposition due to the nature of the conditioning chemical used. The writer has no available data on whether stage heaters show the same deposition, but it is obvious that the high pressure system also solves this question.

(2) While the primary object of the high pressure system is to avoid deposition of scale in economizers and feed lines, it is apparent that it gives a flexibility of control which is far superior to adding the chemical directly to the feed water heaters or hot wells.

(3) The cost of installation of such a system is very moderate. Some of the limitations are:

(1) It is not as adaptable to the needs of a very small plant as it is to a very large plant.

(2) It requires technical supervision of a better order than is required by the other method.

This paper does not attempt to go into all the chemical phases of the problem. There is an abundance of literature on the subject of boiler water conditioning by means of the Hall system, which has been published by the various societies. We could not close this paper without stating our genuine indebtedness for the cooperation of both the Operating and Design Departments of the Corporation which made this development possible.

* * *

A lively discussion followed the presentation of Mr. Markson's paper in which the economic aspects of the installation, labor etc., were discussed.

In concluding the author announced that his company had developed an automatic control which would take care of reasonable variations in make-up. He pointed out, however, that this control would not take care of extreme fluctuations such as are found in some industrial plants.

The author also presented some cost figures which indicated that a complete system such as he described would cost about $8,000, plus $250 per boiler. This figure included two high pressure pumps and supply tanks, and was derived from their costs on two installations of four and twelve boilers respectively.

Progress in the Use of High Pressure Steam

By J. B. CRANE
Combustion Engineering Corporation, New York

This paper was presented at a meeting of the Metropolitan Section of the A. S. M. E. March 25, 1930. The author briefly reviews the progress to date in the use of steam at high pressures, and discusses theory and practice in this field as exemplified in the high pressure plants installed during the past eight years. In his conclusion, the author expresses the opinion that the day is not far off when high pressure power stations, centrally located and operating on a most economical basis, will supply both power and process steam to meet the requirements of surrounding industries. Appended to this paper is a supplementary article by Mr. Crane on foreign practice in the use of high pressure steam.

THE use of high pressure has been consistently advocated by a large number of engineers for a great many years. The use of reheating between a high pressure unit and low pressure unit was also advocated many years ago. In 1858 John Blanchard, an American engineer, installed an improved steam generator on the John Faron, a boat plying between New York and Haverstraw, a distance of 40 miles. This unit consisted of a return tubular boiler with a superheater, a reheater, a water heater or economizer and with an air heater located in the flue between the boiler exit and the stack. It excited much comment at the time and was described in the public press and in the *Scientific American* of July 30, 1859. The high pressure engine operated at 80 to 100 lb. pressure with 80 deg. fahr. superheat, and exhausted at 30 to 35 lb. pressure to the low pressure condensing engine. Water and coal were weighed on the boat and runs were made with interested parties on board; reports were made and sworn to showing one half the coal consumption that had been formerly required. One trip was made to Albany to confirm the figures given on the short run. On these tests, forced draft was used and the escaping gas temperature to the stack was only 230 deg. fahr.

The drawings A and B, Fig. 1 show two arrangements of Blanchard's idea. If only high pressure steam was to be used, the unit consisted of boiler, superheater and feed water heater or economizer as shown in B. If steam was to be used in a condensing engine or for manufacturing purposes, then the steam was exhausted from a high pressure engine into a second heater and the unit consisted of a boiler, superheater, reheater, feedwater heater or economizer and an air heater as shown in A.

In 1903 de Ferranti of Italy became very much interested in chasing stray heat units, and proposed and secured patents on several combination arrangements for reheating in several different ways. He also installed a turbine in the stack with the shaft extending through to the generator. This reduced radiation losses from the turbine and increased the efficiency of the unit.

The complications of these various arrangements combined with relatively lower costs for fuel, coupled with the facts that there were no large concentrations of power and that suitable materials were lacking for manufacturing apparatus at a reasonable cost, prevented the development of such equipment until after the late war. One of the things that largely contributed to this development and served to focus attention on the particular problems involved and to interest many engineers, was a series of papers in 1923 presented before the A.S.M.E. and published in volume No. 45. These were:

The Margins of Possible Improvement in the Central Station Steam Plant—Robinson.
High Pressure, Reheating and Regenerating for Steam Power Plants.—Hirshfeld and Ellwood.
Economy Characteristics of Stage Feed Water Heating by Extraction.—Brown and Drewry.
Reheating in Central Stations.—Wohlenberg.

At that time the properties of steam for the higher pressures were an uncertain quantity and studies had to consider such a situation. Research work was started and today fairly complete and reliable information is at hand.

In the same year the Boston Edison Company installed a 3000 kw. turbo-generator for 1200 lb. pressure, with the necessary boiler, superheater and reheater, to generate power with this high pressure steam and exhaust into their 350 lb. pressure system. This was in an effort to find if theoretical results could be obtained in practice, to develop suitable materials and apparatus for this pressure, and to ascertain what troubles might be expected to develop in operation. About the same time the Masonite Corporation installed a 400 hp. boiler for 1000 lb.

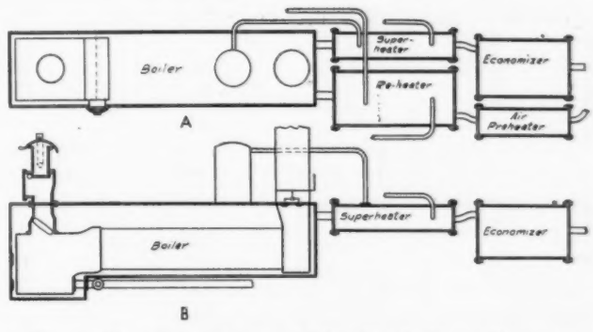


Fig. 1—Two arrangements of Blanchard's Steam Generator developed in 1858

at Laurel, Miss. This unit was to explode wood fibre. A similar unit for 1200 lb. was installed the next year by the Consolidated Safety Valve Company for testing safety valves. Before this, installations had been put in for 650 lb. pressure using the reheat, regenerative cycle, but the plant at Boston was the first attempt to take the maximum advantage of the reheat, regenerative cycle, using a single stage of reheat with available temperatures for materials that could be readily secured.

Theory of High Pressure and Temperature

At one inch back pressure, steam contains 1094 B.t.u. and the latent heat of 1047 B.t.u. is lost in the condensing water. By bleeding the turbine at some higher pressure and using the latent heat to heat feed water some power is secured, the latent heat is transferred to the feed water and the condenser is reduced in size by the amount of steam thus bled. The net B.t.u. lost in condensing water or the equivalent B.t.u. per lb. of steam is thus reduced. The amount of steam to be used in this manner is limited, and, while two stages of bleeding are usually justified, the third stage becomes a study between economizer surface against heater surface less saving in condensor surface; four or more stages of bleeding are rarely justified. The higher the pressure, the higher the feed water may be heated by bleeding the turbine, but where a high and low pressure turbine is used the high bleed point is usually the exhaust from the high pressure turbine.

An effort is made to simplify the arrangement at the expense of the maximum efficiency that could be obtained by adhering strictly to the theoretical conditions as to reheating and bleeding. Some of the early studies stuck rather closely to theoretical considerations and the first cost of equipment was so high as to throw the high pressure plants out of consideration. Later studies combined as much standard equipment as possible, and in this way brought the first cost within reasonable limits. With the development of apparatus and a more thorough knowledge of the action of materials, the possibility of the use of high pressure steam has become much easier to determine.

In efforts to secure the advantage of a higher heat head than was available at 400 lb. there are three methods possible.

1. Development of the low pressure stages of the turbine so that moisture is thrown out without causing trouble in the low pressure stages.

I understand some of the turbine manufacturers feel that they have designs that will accomplish this result, and some experimental installations are in course of erection.

2. Raise the initial temperature and in this way raise the initial pressure that can be used with a single stage of superheat.

By using an initial temperature of 850 deg. fahr. it would be possible to use 500 lb. pressure at the turbine. This is not so far away. While the engineers in the A.S.M.E. discussion in 1923 thought 700 deg. fahr. the maximum safe temperature, there is one installation abroad at 850 deg. fahr., several in this country at 750 deg. fahr., and our engineers feel that superheaters can be designed today for 830 deg. fahr., using carbon steel tubing, and for 1000 deg. fahr. or higher using alloy tubing for that section of the superheater above 800 deg. fahr. The author knows of but one experimental job in the United States planning to use 1000 deg. fahr.

3. Use an initial temperature of 800 deg. fahr. and as the superheat is used in the turbine reheat the steam from stage to stage to maintain an isothermal condition.

This of course makes a very complicated arrangement and practically all the jobs now being installed superheat the steam 750 deg. fahr. to 775 deg. fahr., and this steam is introduced into a high pressure turbine at 1200 lb. pressure. The steam is exhausted from the high pressure turbine at 85 to 400 lb. pressure, having from two per cent moisture to 20 deg. fahr. superheat. The steam is then reheated to give the proper quality of steam at the outlet of the low pressure turbine. The reheater may be of the radiant or convection type in the setting of the steam generating unit or a steam reheater or a combination of the two. Several detailed methods of comparing these various theoretical arrangements

TABLE I
TURBINE PRESSURES AND TEMPERATURES

Name of Plant	Primary Press.	Primary Temp.	Primary Ex. P.	Primary Ex. T.	Secondary Press.	Secondary Temp.	Method of Reheat	Stages of Bleeding
No. 3 Edgar	1300	700	370	500	360	725	Gas	Three
Lakeside	1250	725	325		290	720	Gas	Four
Northeast	1200	725	315	486	290	735	Gas	
Holland	1200	750	400			750	Gas and steam	Four
Deepwater	1200	725	385			725	Sep. boiler	
Jersey Central	1200	750					Gas and steam	
P. G. Z. E. G.	1200	750					Sep. boiler	
Houston	1200	820				685	Sup. and Sat. St.	
San Antonio	1200	750						
Ford Motor, Fordson plant	1230	725	85	320	85	550	Steam	Four

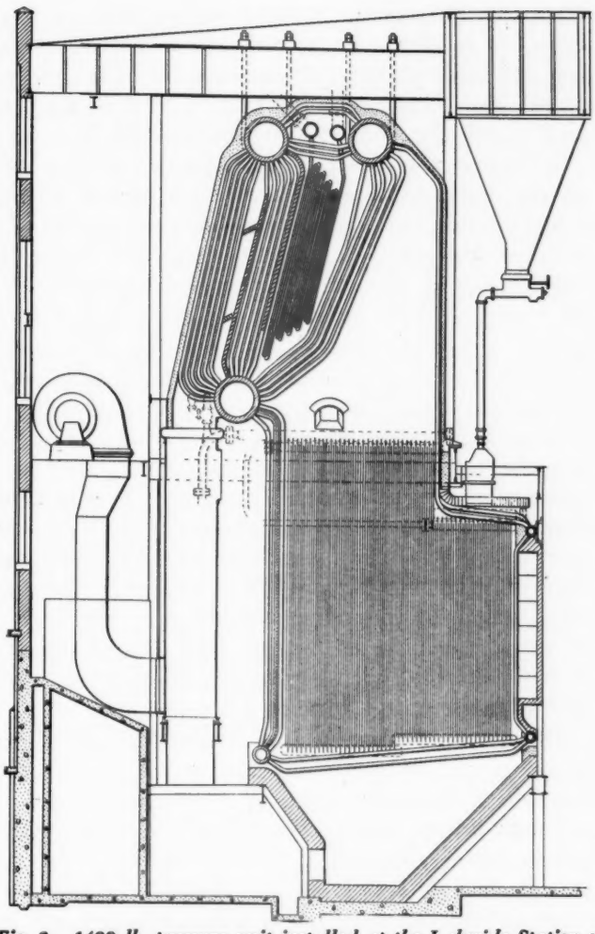


Fig. 2—1400 lb. pressure unit installed at the Lakeside Station of The Milwaukee Electric Railway & Light Company

are shown in the articles heretofore referred to and will not be discussed here.

Combinations of some of the installations are shown in Table 1.

It will be noted that some of the plants listed use four stages of bleeding, but at Holland and probably at some of the other plants the fourth stage of bleeding did not pay for heating purposes alone but was installed to use as a de-superheater in case it became necessary to deliver steam from the high pressure boiler and the high pressure turbine was out of commission. The type of reheater to be used is influenced largely by local conditions. At Edgar a convection type gas reheater is used. The first unit at Lakeside had a radiant type of reheater which was as satisfactory, as the unit operated at a high load factor, but on a subsequent unit a convection type of reheater was used on account of a more variable load characteristic. At Holland and Jersey Central, a steam reheater directly over the boiler drum is used to boost the temperature of the reheat steam at low ratings. At Houston, the primary steam will be superheated to 820 deg. fahr. and will pass through a second effect steam reheater. This steam will reheat the steam from the primary reheater in which the steam has been reheated with saturated steam from the high pressure boilers, to 685 deg. fahr. and the high pressure steam will enter the primary turbine with a total temperature of about 720 deg. fahr.

At the Fordson plant of the Ford Motor Company, it was impracticable to place the high pressure turbine near the boilers, and it became necessary to use superheated steam from the high pressure boilers for reheating.

All of the above installations, except Deepwater, are for central stations. At Deepwater, the steam will be used for process work in an industrial plant after being used in the plant for producing power.

One industrial plant proposes to generate steam at 1800 lb. pressure and manufacture all the electricity for the industry with the steam required for process work. Many other plants are using steam at a lower pressure with the same end in view. Here it is a case of balancing the power requirements against the steam available and to generate steam at a pressure sufficiently high to produce the requisite amount of power.

In all high pressure work, it is necessary to use good water for the boilers. It must be distilled and deaerated, and as pure water readily absorbs all kinds of impurities the water must be carefully watched to see that materials detrimental to the boiler are not carried into the boiler, or, if carried in, means must be devised to eliminate them from the circulation before damageresults.

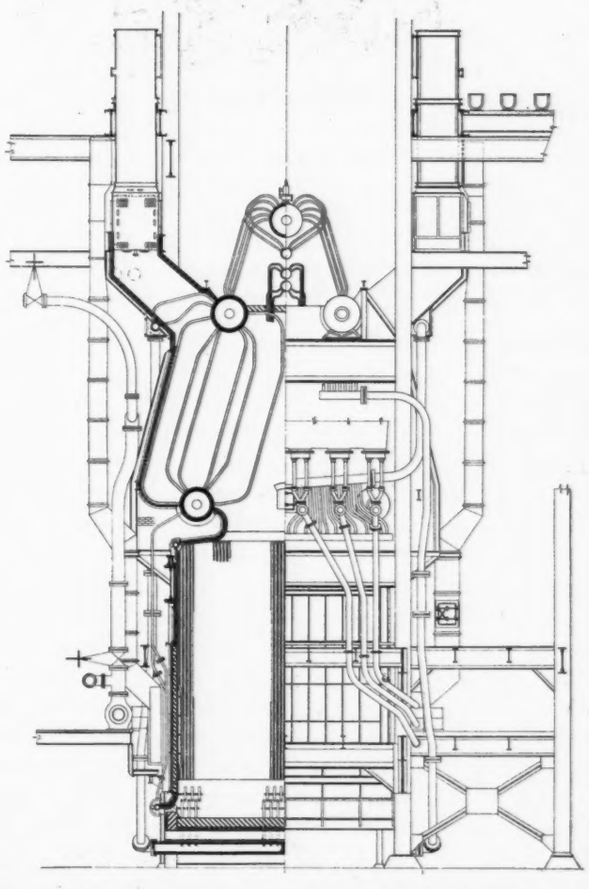


Fig. 3—One of two 1400 lb. pressure units being installed at the Fordson plant of the Ford Motor Company

When using condensers, the make-up is usually around 1 to 2 per cent and the use of evaporators presents no difficulties. In industrial work, where

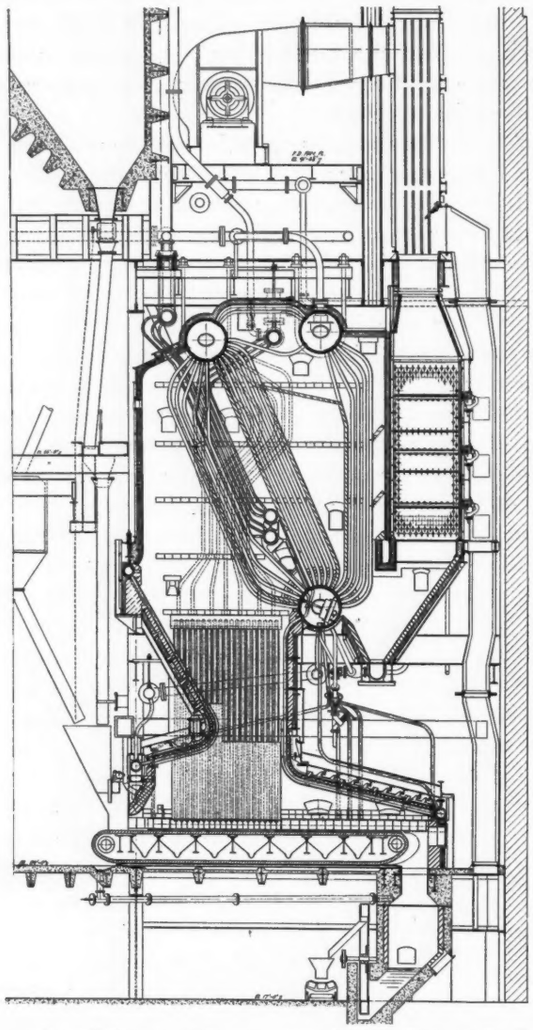


Fig. 4—One of three 700 lb. pressure units installed at the Grand Avenue Station of the Kansas City Power & Light Company

a large amount of the steam is used for process and where only a small amount of condensate is returned to the hot well, it would be impractical to evaporate the water required for the boilers. In such cases the evaporators can be used for making all of the steam required for process work, and the exhaust steam from the turbine or engine can pass through coils in the evaporators, so that the high pressure steam circulates in a closed system and requires a very small amount of make-up, and raw or treated water can be used for process work. The only drawback to this scheme is that it requires about 50 deg. difference in temperature between the exhaust steam from the turbine or engine and the temperature of steam to be used for process work. This is necessary to make an economical evaporator. Such a scheme cannot be used where the requirements for power necessitate an excess amount of steam over that required for process work, or where the maximum use of process steam does not coincide with the maximum demand for power. In such cases, it is necessary to provide a turbine which can be bled at the pressure required for process work, and means must be provided to bring practically all the condensate back to the hot well.

A large amount of the credit for the development of the 1,200 lb. pressure cycle for central station work goes to Moultrup of Boston, Anderson of Milwaukee and Jowett of Kansas City, who were the first to install and put in operation plants for this pressure. Gilbert at Reading contributed a large part of the research work for the newer plants that have gone in, and by repeated conferences with manufacturers of equipment, was able to develop apparatus that was more economical to install and met the requirements in a better way. The earlier three plants were installed on top of low pressure plants already in operation, whereas Gilbert's studies were along the line of developing brand new plants to take maximum advantage of the 1,200 lb. pressure cycle. In industrial work Ryan, formerly of Syracuse and now of Boston, was one of the first to enter the field with a pressure of 800 lb. and Dyer of Philadelphia has gone to 1,800 lb.

The question of materials to be used for the higher pressures and temperatures has caused considerable research to be made in the past few years. Tests on ordinary boiler plate by French of the U. S. Bureau of Standards show that a stress of 10,000 lb. per square inch at 800 deg. fahr. caused the metal to creep six one-hundredths of a per cent in 1,000 hr. This means that at 800 deg. and with ordinary use of a boiler (6,000 hr. per year) in ten years the metal would creep six per cent, which would mean that a drum 50 in. in diameter, at the end of ten years, would be 53 in. in diameter. Various alloys were proposed for drum construction, but, while alloys have been used successfully, it has been in materials of small cross-section, and the question of producing suitable alloys in the amount of material required for drum construction presents considerable difficulties in assuring uniform material throughout the entire structure.

It has been customary to use a high carbon content in materials used for drum forging, and tests made on such materials showed no perceptible creep at 15,000 lb. stress and 700 deg. fahr. Therefore, on drum structure in the United States we are using a steel containing .45 carbon instead of the .20 carbon used in ordinary boiler plate. Some engineers have expressed considerable apprehension about the use of tubing for these pressures and temperatures, inasmuch as the outside temperature per tube is quite a little higher than the inside temperature, and it was feared that hoop stress would cause trouble. This has not happened to any great extent as yet, and, inasmuch as the carbon content of the drums has been raised, there is no reason why the carbon content of the tubes can not be made a little higher, which will tend to help and overcome any

difficulty that might otherwise arise with boiler tubing.

On one of the high pressure jobs in Germany the manufacturer used a nickel alloy tube in the superheater. It was found impossible to maintain this tube tight with a rolled joint, and it became necessary to weld short pieces of carbon tubing on the nickel tubing in order to maintain a tight joint at the header. Further experience with alloy tubes in this country, at temperatures of 1,000 deg. fahr., will, undoubtedly, develop joints that can be kept tight. One of the operators in this country has developed a method of rolling alloy tubing by inserting a red hot piece of metal in the tube at the tube seat and heating it before rolling, and claims that he has been able to secure tight joints with this method.

Conclusion

The next five years will add a large amount of operating experience to that already obtained on high pressure plants. The experience thus far obtained indicates less trouble than was anticipated,

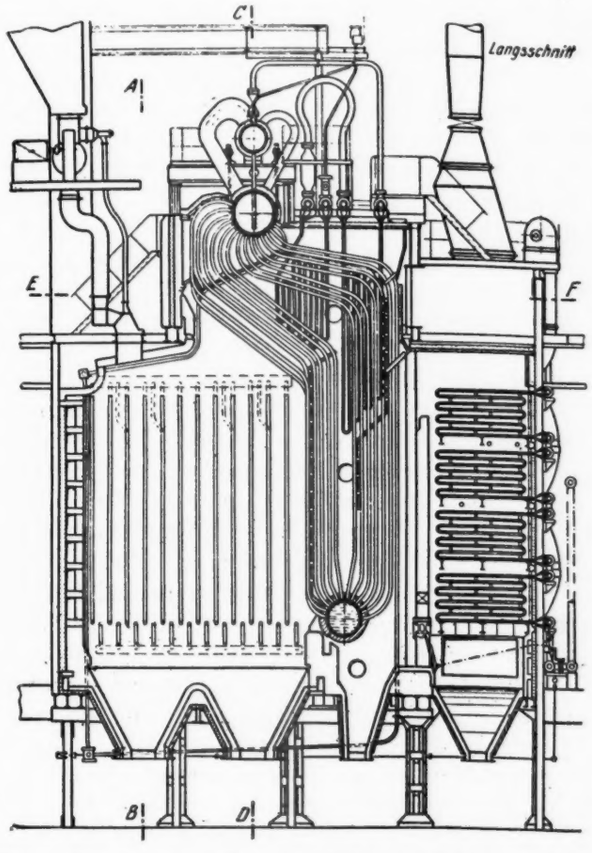


Fig. 5—One of two 1422 lb. pressure boilers installed at Mannheim, Germany

and it is the writer's belief that we will soon see industrial centers in which power houses or a series of power houses will generate power with high pressure steam and deliver steam at lower pressure to the local industries for process work. Such operations will contribute to more successful methods of producing materials by providing a large amount of power at a minimum cost combined with th necessary amounts of heat for process work. This will undoubtedly be combined with the use of waste heat boilers where they can be advantageously used in the operation of furnaces and other processes requiring heat in a different form than steam.

Foreign Developments in the Use of High Pressure Steam*

THE development in the use of high pressure steam has been somewhat different in Europe from in the United States.

Here the first installations were on a commercial scale, and boiler designs in use for the lower pressures were rather closely followed with results that have been satisfactory.

One installation at Mannheim, Germany (Figure 5.) was made in 1928, which rather closely followed our practice. There were two units and each unit was designed for 1422 lb. and for a steam temperature of 878 deg. fahr. with a capacity of 130,000 to 150,000 lb. of steam per hour. As a result of investigations by Dr. Maguerre, Managing Director of the station, the drums were manufactured of Krupp 1½ per cent nickel steel having a tensile strength of 75,000 lb. per square inch, and a yield point of 45,500 lb. per square inch at room temperatures, which, at 590 deg. fahr., was reduced to 66,800 lb. per square inch and yield point of 27,700 lb. per square inch. The boiler tubes were made of Siemens-Martin steel corresponding to the soft carbon steel used at lower pressures, while a nickel steel was used for the superheater tubes. Some trouble was experienced in expanding these superheater tubes, and on one of the boilers, short lengths of carbon steel tubing were welded onto the ends of the nickel steel tubing to obtain satisfactory rolled joints. To use such materials in the United States would increase the cost of manufacture about 30 per cent.

The other European designs have been made on the basis of eliminating expensive forged steel drums and using tubes. To do this the pressure has in most designs been increased to get as close to the critical pressure as possible.

It is also worthy of note that the central stations in this country have been the foremost in going to pressures of 1400 lb. per square inch, while in Europe the central stations have kept to pressures of around 600 lb., and the industrial plants have gone to the higher pressures. Here our turbine manufacturers do not feel that it pays to design units of less than 5000 kw. capacity for these high pressures, while in Europe there is one unit for 1200 kw. capacity at 2400 lb. pressure and 850 deg. fahr., which has been in operation with no trouble

*Presented by J. B. Crane at the March 25th meeting of the Metropolitan Section, A. S. M. E., as a supplement to his paper, "Progress in the Use of High Pressure Steam".

for several years. This unit operates at 6000 r.p.m. with reducing gears between the turbine and electrical generator.

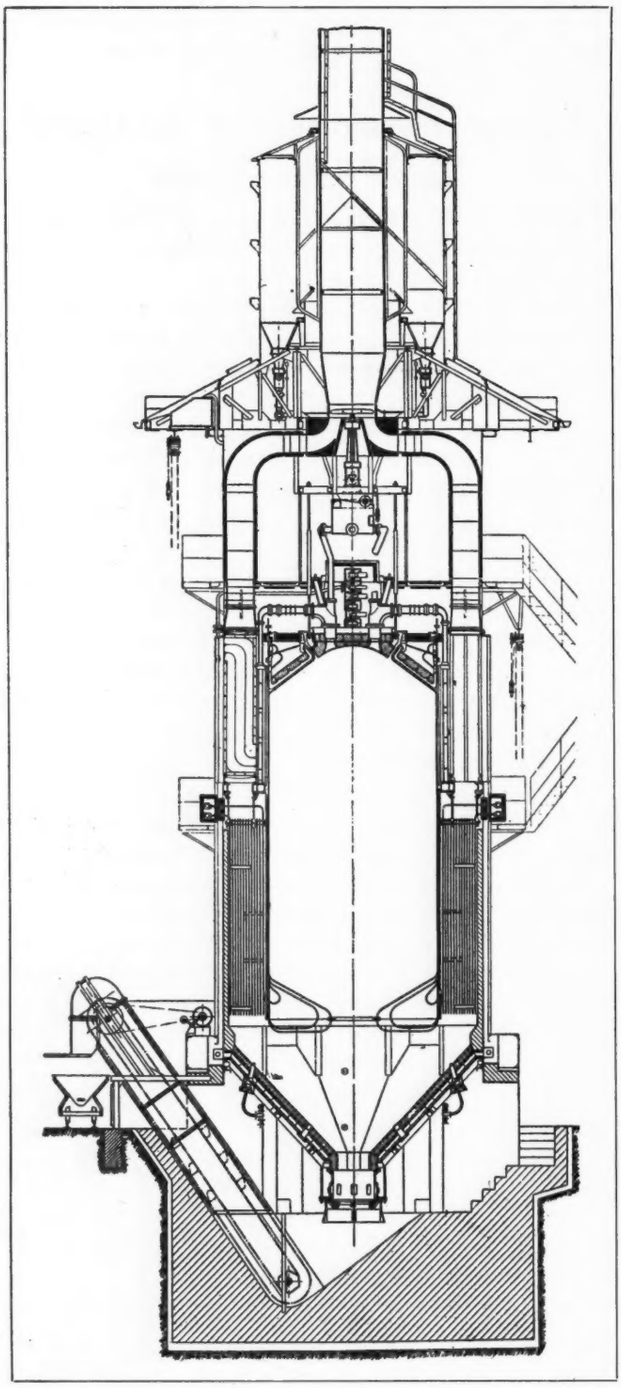


Fig. 6—3200 lb. pressure Benson boiler installed at the works of Siemens-Schuckert, Berlin

One of the outstanding European installations is located at the Siemans-Schuckert Copper Works, near Berlin, Germany, (Fig. 6.). This is a Benson boiler operating at 3200 lb. pressure with a capacity of 66,000 lb. of steam per hour.

The steam passes through a reducing valve to approximately 2400 lb. pressure and is superheated to 850 deg. fahr. It then passes to a 1200 kw., 2400 lb. pressure turbine, and the steam, exhausted at about 800 lb. pressure, is returned to the boiler, reheated to 850 deg. fahr. and passes to an 1800 kw. turbine exhausting at 160 lb. pressure for process work. The two turbines are on the same shaft and connected to an electric generator through reducing gear. At the time of the author's visit to this plant no trouble had been experienced with the 2400 lb. pressure turbine, but some trouble had been experienced with the 800 lb. pressure turbine due to the difficulty of taking care of expansion and contraction, as this turbine is mounted between the high pressure turbine and reducing gear.

Water is supplied to the boiler through a six cylinder single acting plunger pump, operated by 750 kw. synchronous motor. The motor is placed on a shaft with three cylinders set on each side of the motor. This pump has operated satisfactorily, and the pressure at the boiler varies about 100 lb. due to variation in pressure from the pump cylinders. A centrifugal pump was also installed, but to date has not given satisfactory operation.

The steam is admitted to the lower side of a vertical header at the top of the unit, and passes through a tube about 1¼ in. outside dia. This tube is approximately 150 ft. long and projects downward to the bottom of the furnace, where it is looped out to form a water screen, and then looped back and forth, forming one of eight sides of the furnace, and finally entering the upper side of the vertical header. There is no recirculation of water or steam; water enters one end of the tube and issues from the other end as steam. The superheaters are placed in back of four of the eight sides, and reheaters in back of the other four.

The Company was so well pleased with the operation of this unit that last year they began the construction of a second unit of double the capacity, with the furnace arranged in rectangular shape instead of octagonal. The writer understands that the Central Station at Langerbugge, Belgium, which is now operated at 550 lb. pressure and 850 deg. fahr. temperature, has purchased a Benson boiler to have a capacity of 300,000 lb. of steam per hr.

The theoretical advantage of this cycle over the 450 lb. pressure cycle is 15 per cent. The theoretical advantage of the 1400 lb. pressure cycle, of which so many have been installed in the United States, is 13 per cent over the 450 lb. pressure cycle. The argument for the Benson boiler is that this 2 per cent increase in efficiency is obtained at a lesser cost than the 1400 lb. pressure, on account of the omission of drums and the use of less expensive piping.

In the early stages of the operation of this unit, it was felt that the velocity of water and steam in the tubes was high enough to prevent scale formation, and no provision was made for water treatment. After three tubes had been lost due to scale formation

it was decided to use distilled water, and we understand no further tube trouble has developed.

It is also interesting to know that the tubes were butt welded with Thermit welding, and when tube repairs were necessary, the injured part of the tube was cut out and a new piece inserted, the repair being made by Thermit welding.

There have also been several installations in Europe of the Loeffler boiler, with which we are fairly familiar due to the many articles that have been printed in this country. In this boiler, superheated steam is pumped into a pipe located in the water, in an external drum or drums, and the steam coming from this drum passes through the superheating coils where part of it goes direct to the engine or turbine and the remainder returns to the boiler drum. These boilers operate at 1600 to 1800 lb. pressure and we understand give satisfactory service. Here again it is claimed that the installation is less expensive than the drum type of boiler used in this country. However, while the drums are not as thick, owing to the fact that there is no tube ligament to be taken care of, it does require several drums, and it is doubtful if the total overall cost of the unit is any less than for installations made in this country.

Another type of boiler manufactured abroad and designed to accomplish the same results as the Loeffler is the Schmidt Hartmann Steam boiler.

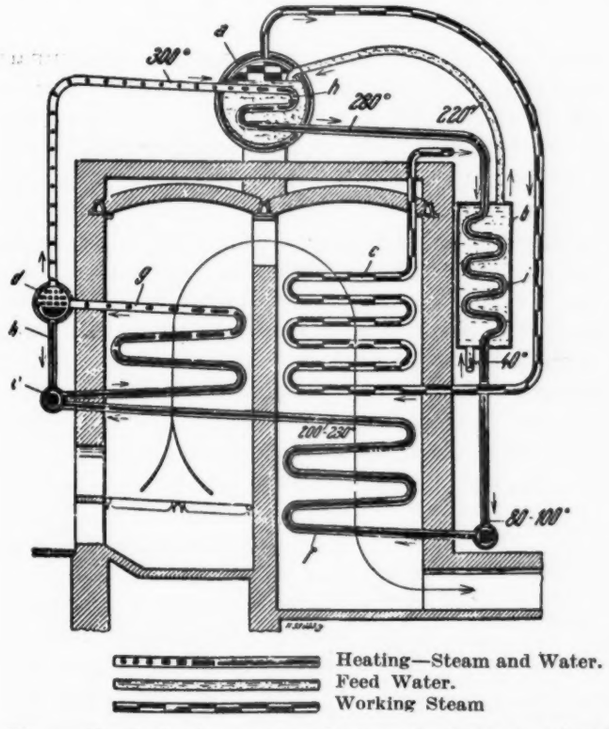


Fig. 7—Sketch showing water and steam circulation in Schmidt high pressure boiler

Here the steam and water form in the water walls of the furnace and are conducted through a coil located in the water of the boiler drum external to the unit (Fig. 7.). The water flows by natural circulation back to the water wall, so that the water in the high pressure part is on a closed circuit and the generation of steam is similar to that in an evaporator when used for delivering process steam. This boiler has the advantage that the water in the high pressure portion can be distilled, deaerated and, working on a closed circuit, requires very little make-up. A locomotive in this country is now being constructed with the use of this type of boiler, and we understand the pressure will be about 1400 lb. It will be noted that it requires about 2400 lb. pressure in the coils in order to obtain 1400 to 1500 lb. pressure in the boiler drum.

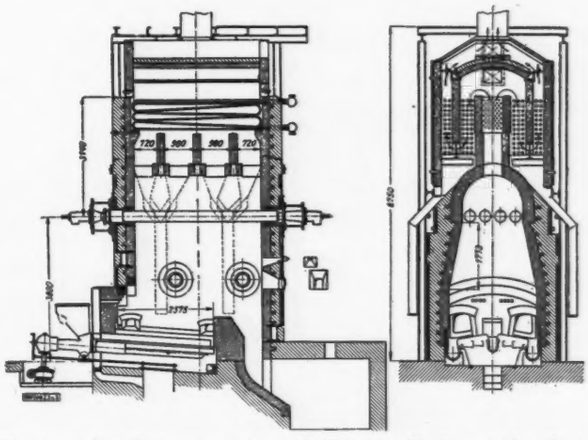


Fig. 8—1470 lb. pressure Atmos boiler installation at the plant of Fors Bruck Company, Fors, Sweden. Dimensions on the drawings are shown in millimeters

Here again the number of drums plus the heating surface in the drums makes an installation that costs practically the same as the construction now used in the United States.

The next type of boiler used abroad which has not been used in this country is the Atmos, (Fig. 8.). In order to reduce the heating surface the boiler tubes revolve, and while it is claimed that no trouble has been experienced with these revolving joints, improvements have been made in this boiler by using smaller tubes on the outside of the revolving tubes in order to increase the capacity of each tube and thus reduce the number of joints to be taken care of with this construction. One of these boilers is operating at Stockholm, Sweden, and generates steam at 1500 lb. pressure and 760 deg. fahr.

Sulzer at their works in Winterthur have in operation a small boiler of their own construction at 1500 lb. pressure.

Foreign practice is in advance of American practice with regard to industrial plants. This is due to the higher cost of fuel and lower cost of materials, so that greater savings can be shown in an industrial plant in Europe for small installations than can be shown in the United States. It is probable that as designs are standardized in America several of our small industrial plants will go to the higher pressures.

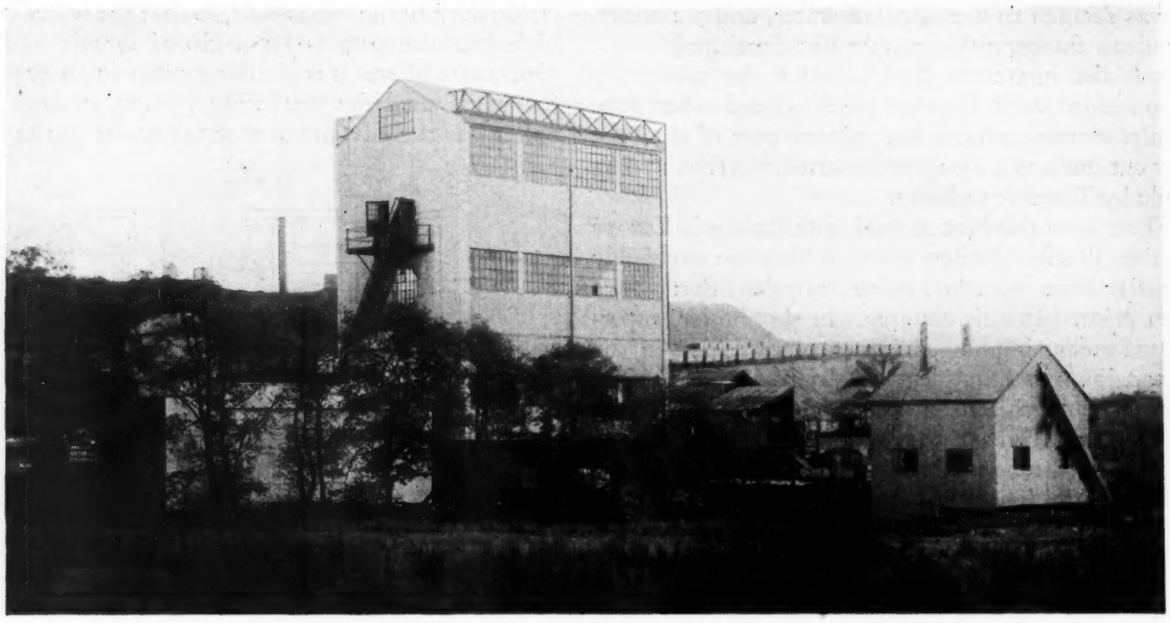


Fig. 1—General view of the Lessing coal cleaning plant at the Yniscedwyn colliery, South Wales

The Lessing Coal Cleaning Process

Anthracite Fines Reduced to Less Than 2 Per Cent Ash by British Method Now Operating on a Commercial Scale

By DAVID BROWNLIE, London

IT is hardly necessary to point out that one of the evils of the use of coal is the ash content, not only as regards the coal user and the general processes of combustion, gasification and carbonization, but also in connection with the net cost of transportation.

The world mines about 1,450,000,000 metric tons of coal per annum, which probably contains an average of say 12 per cent ash. If this coal were washed at the mines by the ordinary gravity flotation methods, using water, and reduced to say 6.0 per cent ash, there would be an immediate saving of the cost of transporting about 87,000,000 tons of ash per annum, as well as a further saving in the enormous cost involved in disposing of this ash. Also the total economy to be obtained through the universal use of coal containing 6 per cent instead of 12 per cent ash would in itself represent a staggering figure.

In this connection great interest attaches to a new development in coal cleaning, the invention of Dr. R. Lessing of London, and controlled by The Clean Coal Co., Ltd., of which Dr. Lessing is a Director.

The first step in this process, which is of the flotation type, is a preliminary cleaning or "de-dusting" of the raw coal to remove all the fine dust below 1/100th in. size, equivalent to all through a 50-mesh screen (Institution of Mechanical Engineers Standard). This is done because the fine dust causes difficulties with the flotation method. The coal is then treated with a strong solution of calcium chloride sp. gr. 1.40 (41 per cent $Ca\,Cl_2$), in which the coal floats and the refuse sinks, the latter being taken away from the bottom of the flotation vessel, while the clean coal is continuously skimmed off the surface of the liquid and allowed to drain. This treatment gives a coal of remarkable character as regards ash content. Thus, for example, material that is extremely difficult to use, such as finely divided refuse anthracite culm, that is, dust and fines with from 15 to 25 per cent ash, is reduced to less than 2 per cent ash, and made as valuable as the graded pea, bean, nut and other sizes. Millions of tons of coal dust and fines of all qualities are at present being thrown away, largely because of the ash content, all of which it is claimed can be treated by the Lessing process, while the great ad-

A substantial reduction in the ash content of coal has obvious advantages both from utility and economic standpoints. While certain flotation methods of coal cleaning have definitely proved their efficiency, they have yet to demonstrate their economic value in any broad sense. However, there are very real possibilities in this field and important progress is being made. In this article, the author describes an English process which has been in commercial operation for the past two years and presents data on the results secured.

vantages of treating good grade screened coal to reduce the ash content to say less than 3 per cent are also obvious.

The basic principle, therefore, of the process is that of "float and sink", using a liquid that is cheap, being a refuse product in the chemical industries, and which is non-corrosive and generally harmless. It is also easily evaporated to the original strength which is advantageous since it is used continuously in a closed circuit, with the original volume maintained by addition. Obviously expensive or corrosive liquids could not be used for the purpose, such as, for example, zinc chloride ($ZnCl_2$) or organic liquids of the correct specific gravity such as a mixture of petroleum and carbon tetrachloride, as suggested by Lessing himself in 1921.

As previously stated, the troublesome, very finely divided material of less than 1/100th in. diameter is first almost completely removed by means of a current of air. This permits rapid draining of the wet cleaned coal following the flotation treatment, and the discarded dust is marketable for burning in pulverized fuel furnaces and for other purposes.

Lessing has long been associated with the problem of mineral matter in coal. In his many contributions on the subject since about 1920, he shows that the Clarain and Vitrain constituents, or bright coal, have only from 1.0 to 2.0 per cent ash, being the mineral matter of the original plant substance; that Durain, the dull coal constituent, has a slightly higher ash, almost entirely pure clay, which is also inherent and which has filtered into the seam during the actual process of formation of the coal, being mixed with the plant particles and not removable from the coal by washing or cleaning processes, but that the Fusain constituent of coal is very different in that the ash, chiefly calcium and iron carbonates with a little clay, has been formed by infiltration of these salts, in solution, into the actual coal seam after its formation, a process which has been going on during the millions of years the coal had lain in the earth. Fusain with a high ash content is also extremely friable, and therefore constitutes a large proportion of the fine dust in the coal caused by mining and handling. Further, it gives rise to all kinds of troubles in coal washing, forming a slurry in the ordinary water washers and preventing the rapid draining of the wet washed coal.

Consequently the object of the preliminary air treatment is to get rid of this obnoxious constituent, leaving the flotation process free to deal with the much simpler problem of the separation of the true coal substance, with extremely small inherent ash, from the external mineral matter added in the mining operations from the adjoining strata. Incidentally this is tending to increase considerably because of the increasing utilization of poorer seams, and also because of machine cutting and explosives.

Following upon the laboratory investigations, The Clean Coal Co. Ltd., operated from 1925 an experimental coal cleaning plant of semi-commercial type, having a capacity of about two tons of coal per hour. From this installation a large amount of valuable data was obtained, representing all kinds of conditions as regards capacity and quality of coal, generally 10 to 20 ton lots of coal being examined at a time.

For example, it was discovered that the removal by air of the dust and fines from the raw coal, to assure proper draining of the final washed coal when using a viscous liquid like concentrated calcium chloride solution, had to be much more thorough than had been thought. The laboratory work seemed to indicate that reducing the dust content of the coal to 5 per cent would be sufficient, but for commercial conditions it was found necessary to reduce the dust content to less than 1 per cent before treating with the calcium chloride.

The first commercial plant was erected in 1928 by The Clean Coal Co. Ltd. at the Yniscedwyn Colliery, South Wales, of Amalgamated Anthracite Collieries Ltd. and has been continued in operation since that time. This plant, which is shown in the accompanying photographs, has a capacity of 20 tons per hour of anthracite culm, that is, dust and fines below 3-16 in. size. It reduces the initial ash content of the culm about 16 per cent down to less than 2 per cent in the final clean coal, which is a highgrade product of an entirely different character from the original material.

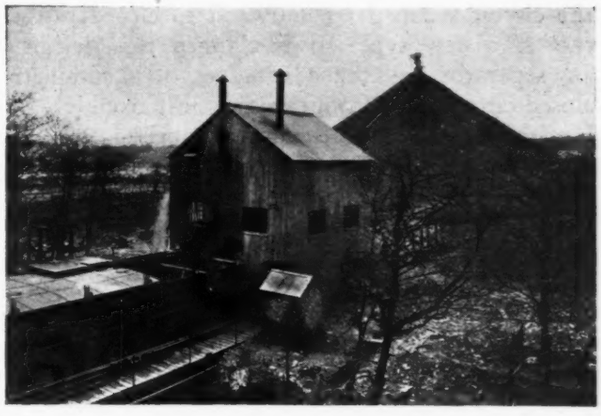


Fig. 2—Refuse pile at Yniscedwyn colliery from which material is taken for treatment in Lessing plant. Concentration tanks for calcium chloride solution are shown on the left

The operation of the plant at the Yniscedwyn Colliery is divided into three main parts, separation of dust by means of air, separation of mineral matter using calcium chloride solution, and re-concentration of the calcium chloride liquor. Fig. 3 shows a diagrammatic illustration of the air and calcium chloride separation portions of the plant. The air separation plant is of special design since the various standard types of air separators on the market will not de-dust the coal down to the limits required.

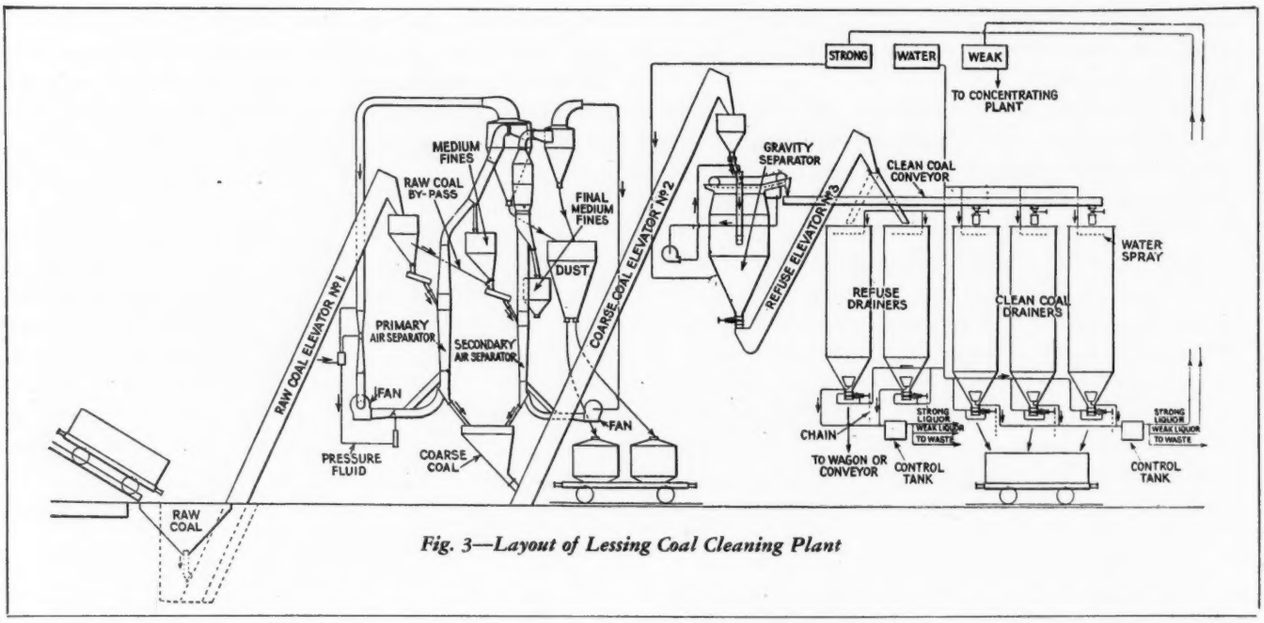


Fig. 3—Layout of Lessing Coal Cleaning Plant

As indicated, the arrangement is a combination of pipes and closed hopper compartments through which a current of air is circulated from an electrically driven blower. The raw coal enters at this end of the plant by means of an endless bucket elevator, the dust being carried in suspension and separated in two stages. The heavier particles descend by gravity to the coarse coal bunker at the bottom and are then taken by an endless bucket elevator to the calcium chloride gravity separation plant. The coal dust is collected from the end of the circuit where it is delivered to closed railway cars of a new type. It is claimed this design of air separator has the advantages of a completely closed circuit, free from external dust troubles, that it effectively separates the dust comprised of 1-100th in. particles or less, requires relatively little ground space, and is low in power consumption.

The dust-free coal from the air separator is delivered to an overhead hopper in the calcium chloride plant, from which it is fed by two or more chutes and controlled feeder tubes to the gravity separator vessel, entering at the sides and being uniformly distributed to the liquid. This separator containing the strong calcium chloride solution is a cylindrical vessel 22 ft. high and 10 ft., 6 in. dia., with a conical bottom and a rectangular top. The particles of coal low in ash immediately rise to the top of the liquor where a continuously operating skimmer or endless chain scraper delivers them to a long horizontal screw conveyor which takes the material along, with any excess calcium chloride liquor, to three large cylindrical drainers, shown on the extreme right. These are about 30 ft. high and 8 ft. dia., the bottom being conical and having a special type of valve that allows of the discharge of the liquor while retaining the coal; grid boxes are also provided for draining off the liquor. The absence of fine dust permits the rapid separation of the coal and liquor, most of the liquor passing back at once to the strong liquor store tank by way of a float control tank.

As the drainage proceeds in the cylindrical containers, a regulated amount of fresh water is sprayed in at the top to wash the coal from the calcium chloride. The arrangement is such that the resulting solution, when weaker than a sp. gr. of about 1.20,

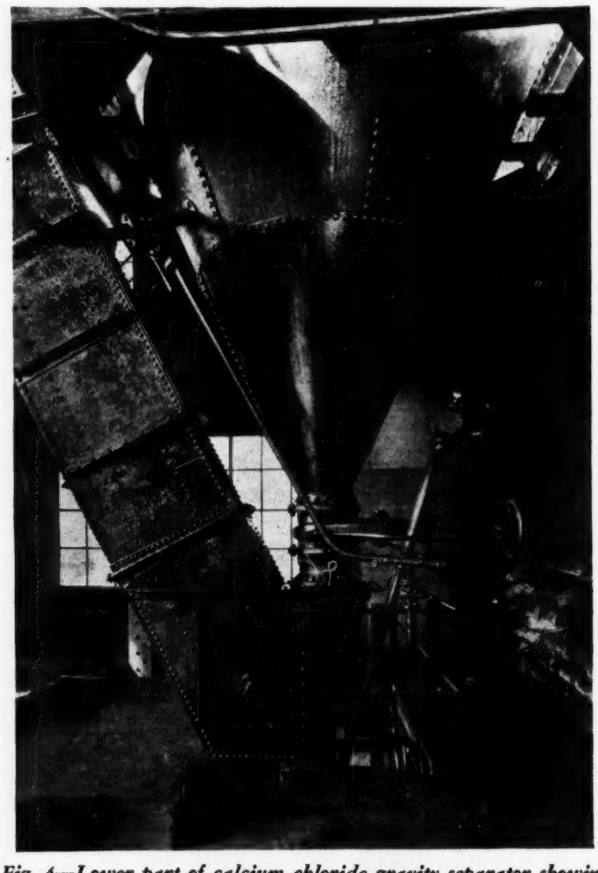


Fig. 4—Lower part of calcium chloride gravity separator showing elevator for removal of high ash refuse

does not mix with the strong solution taken away at the bottom. The final diluted liquor, having a sp. gr. of a little over 1.00, is diverted to a weak liquor tank, the float control arrangement giving an automatic bell signal when the liquor is sufficiently weak to switch over from the strong liquor tank. It is stated that in practice only about ½ gal. of strong liquor per ton of coal is lost, while about 120 gal. of water is used, which can be recirculated if necessary.

The total time required for draining and washing in the cylindrical drainers is only about 1½ hr., after which the material, with very small moisture content, is discharged by opening the valve to cars. The weak liquor separates from the drainers at the rate of about 70 gal. per ton of raw coal, with a sp. gr. of 1.20, and is passed to a simple type of steam heated evaporator where the sp. gr. is raised to the original figure of 1.40. It is then discharged to the strong liquor storage tanks. The steam for the evaporator is provided by a boiler burning washery refuse with about 60 per cent ash.

As typical of the results obtained with the process, using 10 to 20 ton lots of coal in the experimental plant, the figures below are extracted from Lessing's paper before the Second International Conference on Bituminous Coal. They are based on two representative British coals, namely, Durham coking, a high grade quality, and refuse anthracite culm, the yields being given on the air-dry basis. The fine dust separated by the preliminary air treatment is classified as fines and medium coarse, available for pulverized fuel firing or other use, as stated, while refuse is the separated ash material, generally about 55 to 62 per cent mineral matter, which is thrown away on the tip, except for the amount used in the boiler to provide the steam required.

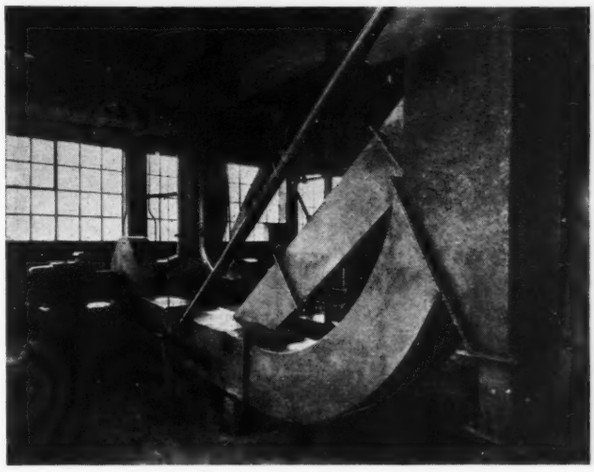


Fig. 5—Lower part of the de-dusting plant

From these figures it will be seen that with a good grade small coal such as Durham coking, 3/8 in. to 1 in., having 17.36 per cent ash and a heating value of 12588 B.t.u. per lb., the Lessing process gives 75 per cent of the coal with only 3.65 per cent ash, having 14480 B.t.u. per lb, while 25 per cent is thrown away as a refuse product containing 59 per cent ash.

Even better results are secured when treating anthracite culm of a size below 3/16 in., containing 16.3 per cent ash and having a heating value of 12020 B.t.u. per lb., a very much more difficult

Screen Size	Durham Coking Coal				Anthracite Culm
	Trebles 3½ —1½"	Doubles 1½ —1"	Singles 1"—⅜	Smalls 1"	Below 3/16 in.
(A) YIELD OF PRODUCTS.					
Fines	.....	.....	.....	13.4%	12.5%
Medium Coarse	.....	.....	.....	10.2%	5.4%
Clean Coal	74.5%	65.2%	75.7%	61.6%	58.7%
Refuse	25.5%	34.8%	24.3%	14.8%	23.4%
Total	100.0%	100.0%	100.0%	100.0%	100.0%
(B) ASH IN PRODUCTS.					
Fines	.....	.....	.....	15.04%	12.85%
Medium Coarse	.....	.....	.....	15.04%	12.85%
Medium Coarse	.....	.....	.....	15.23%	11.10%
Clean Coal	5.02%	4.40%	3.65%	3.25%	1.28%
Refuse	54.14%	62.54%	58.99%	62.00%	56.20%
Original Coal	.....	.....	17.36%	14.82%	16.30%
(C) HEATING VALUE OF PRODUCTS. B.t.u. PER LB.					
Fines	.....	.....	.....	12430	12850
Medium Coarse	.....	.....	.....	12230	13560
Clean Coal	14130	.....	14480	14680	14900
Refuse	.....	.....	.....	3890	5710
Original Coal	.....	.....	12580	12850	12020

material to use in actual practice than the above figures indicate. Fifty-eight and seven-tenth per cent of this coal is converted into a high grade, finely divided anthracite containing actually only 1.28 per cent ash, with 14900 B.t.u. per lb., while 17.9 per cent of the raw coal is also available for use in pulverized fuel firing or briquetting, and 23.4 per cent is thrown away as a refuse product with 56 per cent ash.

The effect of this method of cleaning on sulphur is particularly interesting in view of the troubles that ensue from sulphurous (SO_2) and sulphuric acid (SO_3) in stack gases, a problem that every power station will have to face. Lessing gives, for example, the case of a Durham steam coal which contains 2.29 per cent sulphur, and which, after treatment, yielded 72.2 per cent of clean coal containing 1.49 per cent sulphur, the ash being 3.49 per cent. In the case of the anthracite culm already mentioned, the original sulphur content was 1.18 per cent but the sulphur in the 58.7 per cent of clean coal with 1.28 per cent ash was only 0.7 per cent. This means that the process removes iron pyrites and other inorganic sulphur compounds more effectively than ordinary washing processes using water.

It must be remembered, however, that sulphur is present in coal as fixed sulphur and volatile sulphur, the latter being chiefly in the form of organic compounds forming a part of the coal substance itself and not removable by washing or other purification treatment, any more than the natural ash of the original plant substance. Lessing also stated, an interesting point in connection with hop and malt kilns, that when anthracite is treated on these lines with air and calcium chloride flotation nearly all arsenic is removed in the high ash content refuse.

Obviously the process has some disadvantages, such as the total net cost of the method, the necessity of evaporating the liquor and the fact that the original coal is reduced considerably in weight, as represented by the loss of the high ash content refuse, while in many cases it may not be possible to utilize the fine coal dust to full advantage. The matter is, therefore, essentially one of economics involving the actual net value in given circumstances of the raw coal, coal dust, clean coal, and refuse.

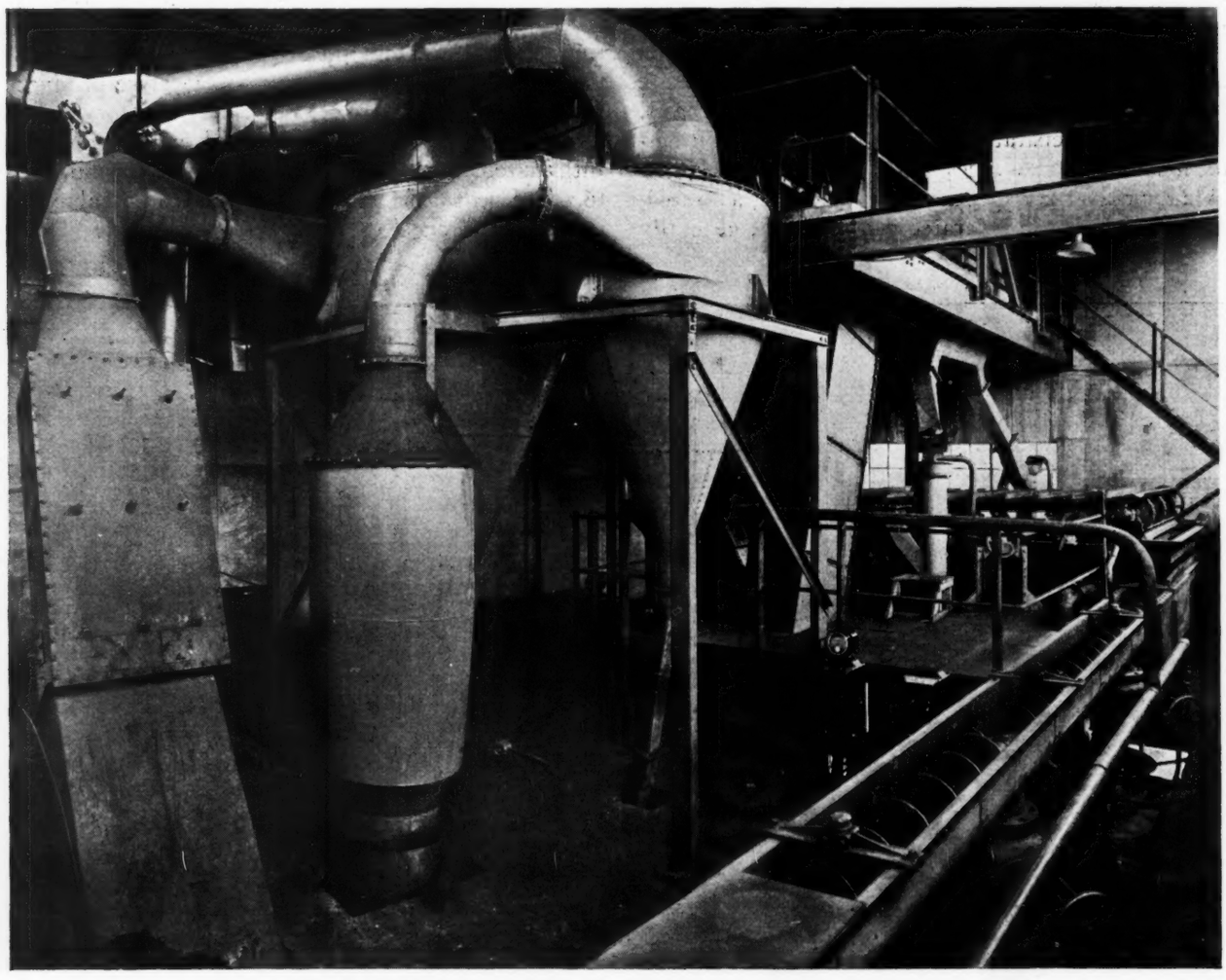


Fig. 6—Upper part of the de-dusting plant and gravity separator

This first Heine Boiler, a veteran of nearly half a century, offers a striking contrast with the large steam generating units of today

Ford Museum To Exhibit First Heine Boiler

THE Ford Industrial Museum at Dearborn, Michigan, has received, as a permanent exhibit, the first Heine water tube boiler, which though nearly a half century old is still complete and in good condition.

This boiler was constructed early in 1882 at the shop of Richard Garstang in St. Louis, Missouri, and was entirely hand made. It was sold to the First Regiment Armory Association in St. Louis and was installed in the new armory building erected in 1882. It continued in service until the armory was destroyed by fire in 1917 after which it was salvaged by the Heine Boiler Company, erected on a pedestal and stood as an exhibit in the yard of the shop at St. Louis until late in 1929.

The principal dimensions of this boiler are:

Heating Surface	263 sq. ft.
Diameter of Drum	30 in.
Length of Drum	13 ft. 2 in.
Thickness of Shell Plate	¼ in.
Thickness of Water Leg Plates	½ in.
24 Tubes	3½ in. dia.
Maximum Working Pressure	100 lb. per sq. in.

Even for the moderate pressure for which it was designed, this boiler would not meet the present standards of construction either as regards workmanship or material. Boiler plate was then bought and sold under makers' brands, little attention being paid to specifications. The use of wrought iron had largely been discontinued, Bessemer steel being generally accepted. However, lapwelded knobbled charcoal iron tubes were universally used. Unfinished punched rivet holes and sheared edges, laborously trimmed up if necessary with hand hammer and chisel, were good workmanship. Nor was the use of drift pins to bring poorly machined holes into line considered a practice of which to be ashamed and a flogging hammer well laid on was an expeditious and effective means of bringing surfaces together. Tube and handholes were drilled because that was the only means available for making holes of that size.

Compared with modern manufacturing methods the practices that prevailed in boiler making when this little boiler was built fifty years ago, seem primitive indeed.

High pressure water tube boilers of such absurdly small size are no longer built and this unit is a veritable pigmy as measured by the standards of modern steam boilers.

Recently one of the steam generating units at East River Station, New York Edison Company, delivered steam at the rate of 1,250,000 lb. per hour.

If this first Heine boiler had operated continuously for the entire 48 years since it was built, 24 hours a day, 365 days a year, it would have produced approximately the same amount of steam in nearly a half century as one of the New York Edison units could produce at maximum rating in less than 11 days.

As a further comparison, it would require nearly 1,600 boilers each having the capacity of that unit of 50 years ago, to equal the steam production of one of the New York Edison boilers at maximum rating.

This little boiler, which represented the best practice of its time, provides a basis of comparison by which we can determine the tremendous progress which has been made in steam generating practice during the past half century.

How to Determine the Moisture in Steam

By B. J. CROSS
Combustion Engineering Corporation, New York

SATURATED steam as it is discharged from the boiler always contains some moisture probably in the form of a mist or fog. The water evaporated by a boiler as determined by weighing must therefore be corrected for this entrained moisture that is removed mechanically.

There are a number of devices for determining the moisture in steam. The simplest and probably the most reliable is the throttling calorimeter. In this device a sample of the steam is expanded or "throttled" through a small orifice and allowed to expand to atmospheric pressure in a chamber open to the atmosphere. From the pressure of the steam in the main and its temperature in the calorimeter chamber, the moisture content may be computed.

As the total heat of steam at atmospheric pressure is lower than at the usual boiler pressures, the excess of heat when the steam is expanded to atmospheric pressure results in superheating of the atmospheric steam. If no moisture is present in the steam a maximum superheat of the atmospheric steam will be obtained. If the actual temperature of superheat is below this maximum, there must be moisture in the steam and some of the heat was used to evaporate this moisture. The amount of heat used to evaporate the moisture divided by the latent heat of the high pressure steam will give the weight of moisture in pounds per pound of steam. This weight multiplied by 100 gives the moisture in per cent.

Expressed in an equation, the per cent moisture in steam,

$$M = 100 \times \frac{H - h - .47\,(T - t)}{L}$$

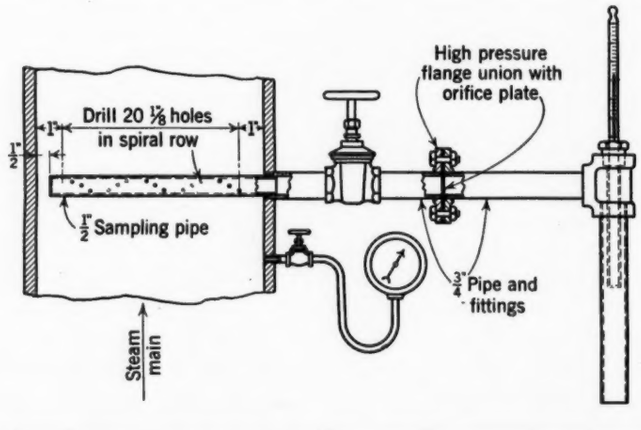
M = per cent moisture in steam
H = total heat of high pressure steam
h = total heat of steam at atmospheric pressure
T = temperature of superheated steam in calorimeter
t = temperature of saturated steam—atmospheric
L = latent heat of high pressure steam
.47 = specific heat of steam

A correction for T is usually determined by sampling the steam when the boiler is operating at very low ratings or when it is banked under pressure. At these times it can be expected that the steam will be practically dry and the maximum superheat will be obtained. A correction equal to the difference between the observed T and the theoretical T is then applied to subsequent readings, for the same thermometer and calorimeter. This is called the "normal correction" and covers radiation losses and thermometer corrections.

The chart on the opposite page has been prepared from the equation given and steam properties from Goodenough's Steam Tables. Atmospheric pressure in the calorimeter chamber has been assumed.

The chief difficulty in measuring the moisture in steam is in obtaining a correct sample. The standard nozzle adopted by the American Society of Mechanical Engineers for collecting the sample consists of a ½-inch pipe closed at one end and drilled with twenty ⅛-inch holes in a spiral row around the pipe. This pipe should extend almost across the diameter of the steam main, with the holes nearest the walls not less than 1 inch from the wall. It should be located in a vertical section of the pipe as close to the boiler as possible.

While the entrained moisture in steam is economically a complete loss, in calculating the heat absorption by the boiler the correction should be made based on only the latent heat of this moisture. The boiler should be credited with the heat necessary to raise the temperature of the moisture in steam from the feed water temperature to the temperature of the saturated steam.



A simple form of throttling calorimeter made up of standard pipe and fittings. This calorimeter should be thoroughly insulated with hair felt or similar material

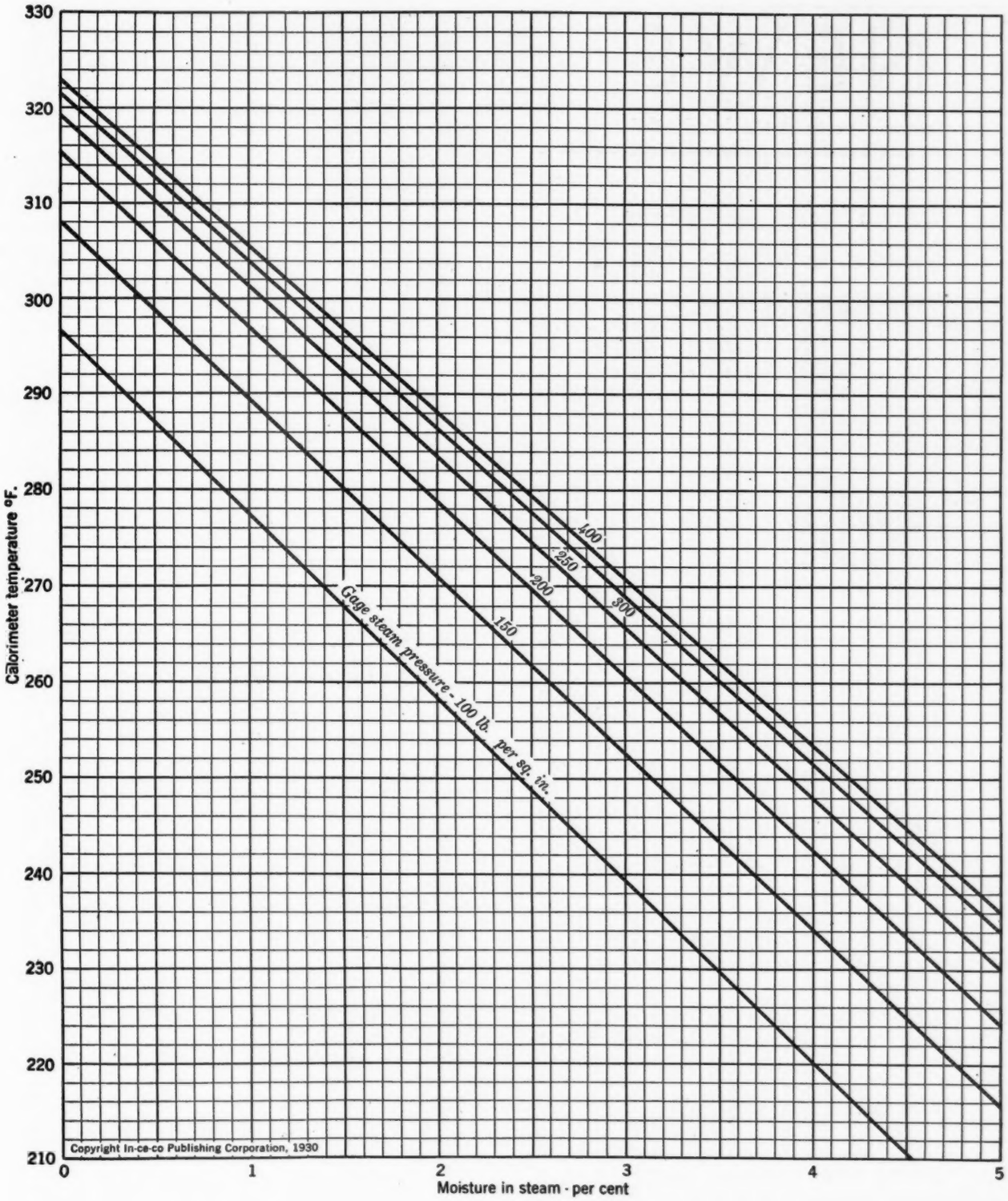


CHART FOR DETERMINING THE MOISTURE IN STEAM

No. 9 of a series of charts for the graphical solution of steam plant problems

NEWS

Pertinent Items of Men and Affairs

Colonel Peter Junkersfeld, Engineering Official, Dies

COL. PETER JUNKERSFELD

COL. PETER JUNKERSFELD, vice-president of Stone & Webster Engineering Corporation, New York, died suddenly at his home at Scarsdale, New York, March 18th. He was sixty-one years old.

Colonel Junkersfeld was born in Sadorus, Illinois, was graduated from the University of Illinois in 1895 and shortly afterwards entered the employ of the Chicago Edison Company, with which organization he was identified for twenty-four years. In 1919 he resigned to become associated with Stone & Webster with which organization he was identified until he resigned in 1922 to become a member of McClellan & Junkersfeld, Inc., engineers and constructors. In 1928 this firm was merged with the Construction and Engineering Division of Stone & Webster and Colonel Junkersfeld became the vice-president of that organization.

Colonel Junkersfeld was a past president of the Association of Edison Illuminating Companies, past president of the American Institute of Electrical Engineers and a past vice-president of the Western Society of Engineers.

He was recognized as one of the outstanding engineering executives of the public utility field.

Muscle Shoals

The War Department has granted the application of the Alabama Power Company and the Tennessee Electric Power Company for a joint contract covering the purchase of power at Muscle Shoals. In a letter to Senator Black of Alabama, Secretary of War Hurley says that the Department has taken great pains to see that the contract safeguards the interests of the government. The contract can be cancelled on thirty days' notice and is subject to any legislation passed by Congress. Secretary Hurley says that the Department's purpose is to derive additional revenue from the Muscle Shoals project, pending final disposition by Congress.

H. B. Rust, president of the Koppers Company, Pittsburgh, and John S. Brooks, Jr., general counsel of the company, have been elected to the Board of Directors of the United States Electric Power Corporation, following the acquisition by the Koppers Company of large stock holdings in United States Electric Power. The Koppers Company is the holding company for the Mellon interests in the gas and by-product coke field.

H. Boyd Brydon, chief mechanical engineer, Byllesby Engineering and Management Corporation, Chicago, resigned effective March 17th, after serving 21 years in the Byllesby organization.

The American Society of Heating and Ventilating Engineers has moved to new and larger quarters on the 31st floor of the New York Life Insurance Building, 51 Madison Avenue, New York. The former offices of the society were in the Engineering Society Building where headquarters were maintained for the past 19 years. During this time the membership increased from 400 to over 2,000.

Consolidated Gas Plans Control of New York Steam

The New York Steam Corporation through an application to the Public Service Commission for approval of a new common stock issue of 14,000 shares, has revealed the plans of the Consolidated Gas Company, New York, to obtain control of the steam corporation.

The Consolidated Gas Company has agreed to purchase the entire new 14,000 share issue for $400 a share. The $5,600,000 thus raised, will be used in part for improvements, the remainder to go into the sinking fund.

The New York Steam Corporation, a $50,000,000 company, owns and operates four plants serving important areas from lower New York to the Central Park District. Its assets have quadrupled in the past eight years.

Leeds and Northrup Company, Philadelphia, Pa., announces the removal of its Cleveland office to 1941 Union Trust Building, Cleveland, Ohio.

Stone & Webster, Incorporated, Boston, Mass., and Engineers Public Service Company have effected a merger according to an announcement of the committee representing the common stockholders of the latter company. It is understood that approximately 80 per cent of the outstanding common stock of Engineers Public Service is now either owned by Stone & Webster or has been deposited under the terms of the merger plan.

Capital Expenditures for Light and Power Exceed Those for Railroads

Capital expenditures by the electric light and power companies for additions, betterments and new construction during the six years from 1924 to 1929 inclusive, exceed similar expenditures by the railroads, according to figures prepared by the Statistical Research Department of the National Electric Light Association.

During these six years the power companies spent for these purposes $4,865,000,000, while the railroads spent $4,809,959,000. It is interesting to note that, because of unprecedented demands for service, in 1924 the light and power companies spent $908,000,000, which is in excess of the estimated budget for 1930, and in 1925 spent $846,000,000, which is very close to the estimated budget for this year.

According to the Bureau of Railway Statistics, the disbursements authorized by Class I railroads in 1929, which were unexpended and which are carried over into 1930, exceed $600,000,000. Projects for which this money was provided, together with other projects authorized, will be completed as rapidly as possible, but, the Bureau says, the amount of the additional authorization cannot be estimated now.

The following table shows the capital expenditures of the railroads and the light and power companies during the past six years:

Year	By Steam Railroads	By Electric Light and Power Enterprises	
1924	$874,744,000	$908,000,000	
1925	748,191,000	846,000,000	
1926	885,086,000	772,000,000	
1927	771,552,000	794,000,000	
1928	676,665,000	754,000,000	
1929	853,721,000	791,000,000	(preliminary)
Total since 1923	$4,809,959,000	$4,865,000,000	

Natural Gas Convention

Fifteen hundred representatives of the industry are expected to attend the 1930 Natural Gas Convention, which will be held under the auspices of the American Gas Association at New Orleans, La., May 5th to 8th. Headquarters will be at the Roosevelt Hotel.

H. C. Morris, of Dallas, Texas, Chairman of the Program Committee, said that while this convention will be known as "The Western Natural Gas Convention," it will be open to all natural gas men in the country. He added that the program will feature outstanding problems and points of interest to the industry.

B. J. Mullaney, president of the American Gas Association, and Alexander Forward, Managing Director of the Association, are among those who are expected to deliver addresses.

$100,000,000 Natural Gas Line Planned for Chicago

Two pipe lines for conveying natural gas from the Texas Panhandle fields to Chicago are now under consideration. The companies principally interested in the project are the Standard Oil Company of New Jersey, Texas Company, Cities Service and the Insull interests. It is believed that Skelly Oil, Phillips Petroleum, Continental Oil Company, Columbian Carbon Company and the United Carbon Company may also be identified with the project.

Ford, Bacon & Davis of New York have been mentioned as engineers on this project. This firm was the engineer in the building of the two principal natural gas pipe lines now in operation, one from the Amarillo fields in Texas to Denver and the other from the Munroe and Richlands Parish fields in Louisiana to Birmingham and Atlanta.

The 900 mile line to Chicago, when completed, will be the longest natural gas pipe line in the world. Based on a 24-inch line, it is estimated that the total cost of the project will approximate $100,000,000.

Dr. Karl Taylor Compton, head of the physics department of Princeton University, has been appointed president of Massachusetts Institute of Technology, effective in July, to succeed Samuel W. Stratton who will become chairman of the executive committee.

Oil Burner Equipment Exposition

An exposition will be held at the Hotel Stevens, Chicago, April 7th to 12th, in connection with the seventh annual convention of the American Oil Burner Association.

The sixty-eight exhibitors include not only manufacturers of oil burners and accessories but also oil companies. This will be the first exposition held by the association in which the oil companies have been represented.

The convention program includes the following speakers: E. V. Walsh, of the Timken Oil Burner Co.; O. P. Harris, of the Petroleum Heat and Power Co.; E. S. Brinsley, Credit Investment Trust of New York; Carl E. Widney, Kling-Gibson Co. of Chicago; S. E. Andros, Quaker Manufacturing Co., Chicago; H. W. Sweatt, Minneapolis-Honneywell Regulator Co.; Chester Carr, E. W. Carr & Company, Inc., New Orleans; William Webster, May Oil Burner Corporation, Baltimore.

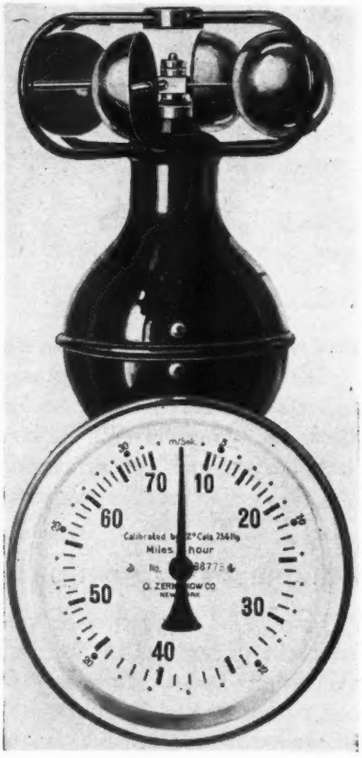
Foster Wheeler Corporation, New York, announces the address of its Los Angeles district office as 342 Petroleum Securities Building, 714 West Tenth St., Los Angeles, Cal.

NEW EQUIPMENT

of interest to steam plant Engineers

An Air Velocity Meter

THE O-Z Anemo Tachometer, manufactured by O. Zernickow Company, New York, is an air velocity meter which combines the features of the "Robinson" Cup Cross and centrifugal tachometer. On the extension of the pendulum shaft, the cup cross is located. When exposed to an air current, the cup cross receives a very definite



average angle velocity, in such a manner, that the average absolute speed of the cup center is in approximately constant relation to the wind velocity. The result is transmitted from the pendulum in the usual manner to the hand of the instrument and an accurate scale makes the reading of the wind velocity and its fluctuations very easy indeed. The reading is practically unaffected by altitude or barometric pressure and can, therefore, be used directly.

It is immaterial whether the suction or pressure conduit is tested, whether the current is laminary or turbulent, even considerable dust contents, which make pitot tube measurements impossible, have no bad influence on the Anemo Tachometer.

All parts of the instrument, such as ball-bearing spindle, pendulum and indicating mechanism, are enclosed fully dust-proof in a strong and handy aluminum housing. The cross cups are protected by a wire guard. With the handle attached, the O-Z Anemo Tachometer weighs only 2 lb. and can be used even in unfavorable cross sections.

The dial has double graduation, from 10 to 70 miles per hour and 5 to 35 meters per second. Other ranges and graduations can be made to order.

A 34 Tube Gage

AN outstanding development in draft gages, is a new 34 inclined tube gage, recently designed by Lewis M. Ellison and built by the Ellison Draft Gage Company, Chicago, Ill. It comprises two units for the new forced draft multiple retort Taylor stokers for the Beacon Street station of the Detroit Edison Company.

Each stoker is equipped with 34 venturi nozzles in a common wind-box, pointing up towards the grate. In each nozzle is a damper for controlling the air flow to a uniform rate, as indicated by a straight line differential reading on the gage, one tube for each nozzle.

The zero end of the gage is connected with the wind-box under a common pressure. At the other end of the gage, each of the tubes is piped to one of the nozzles in the grate side of the damper, and is sealed up to six inches pressure.

The scale is ten inches long and is provided with one inch sliding movement for zero adjustment. The tubes are spaced on one inch centers, with the scale graduated to read one inch differential pressure in .01 in. on one side of the tube, in black graduations, and the other side of the tube to read the air flow, or square root of the differential pressure, in red graduations.

The gage frame is constructed of 1/4 in. brass plate, 36 in. wide, and is provided with four adjustable supports with floating bearings, one in each corner, for leveling the gage on a metal stand.

In the construction of the gage frame, great care was exercised to minimize the weaving of the frame, and to provide means for placing the gage in the same position, with reference to tube inclination, in which it was standardized. The gage is leveled by a portable bench level, thus eliminating fixed level breakage.

In the calibration of the 68 tubes at 1/4 in. intervals, nearly all points checked exactly, none exceeding an error of .005 in.

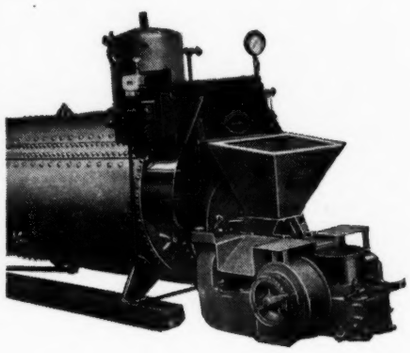
It is a rather remarkable coincidence that 34 years after the designer introduced the first inclined tube gage, this 34-tube gage should mark the span of time, by a tube for each year of effort by the designer to make the inclined tube gage the instrument of usefulness it is today in its wide field of application.

New Stoker For Internally Fired Boilers

THE new Leffel Stoker manufactured by the James Leffel & Company, Springfield, Ohio, has been developed to provide an automatic stoker which will operate satisfactorily and efficiently with Scotch marine type boilers.

The stoker, which is shown attached to a Scotch marine type boiler in the accompanying illustration, is made in sizes from 15 hp. to 200 hp. and can be readily applied to boilers of this type which are already in use.

When a boiler is fired by hand, it is impossible to maintain correct proportion of fuel and air in the fire box at all times, since every time the fireman opens the doors cold air will rush in and lower the temperature in the fire box. With stoker firing this condition is eliminated, and uniform furnace conditions are obtained.



The new Leffel stoker is electrically operated (although steam turbine drive can be provided if desired) and the rate of firing, as well as the amount of air admitted to the fire box, is automatically controlled by the steam pressure of the boiler.

The fire is fed from underneath and the ashes fall off at the sides of the fire box as the coal slowly rises. There is never any choking of the fire by fresh fuel as the combustion is always at the top.

The machine is sturdily and simply constructed, so that it requires a minimum of attention. The gearing is totally enclosed and dust proof, operating in an oil bath. The stoker itself takes up no more room than would be required for a man in the act of shoveling coal into the fire box. Under average conditions it is necessary to fill the hopper at intervals of approximately two hours, an operation which can be performed by the most inexperienced employee.

REVIEW OF NEW TECHNICAL BOOKS

Any of the books reviewed on this page may be secured from
In-Ce-Co Publishing Corporation, 200 Madison Avenue, New York

Steam Tables and Mollier Diagram

By Joseph H. Keenan

THIS book is published by the American Society of Mechanical Engineers and presents the most recent and accurate tables on the properties of saturated and superheated steam available at this time. Prof. Keenan's values are based upon the new data assembled by the A. S. M. E. Special Research Committee on the Properties of Thermal Steam which has been carrying on important experimental work for the past nine years.

These tables represent the first attempt in this country since the formation of the A. S. M. E. research committee on the thermal properties of steam to place before engineers complete tables covering the range of pressures and temperatures that are now being used and based largely on experimental data rather than extrapolated values. While they are not to be looked upon as tables of ultimately correct values such as it is hoped will be arrived at by further experimentation and the cooperation and agreement of international authorities, they do represent the best, in America at least, that our knowledge permits at present.

The book is attractively printed and bound in cloth covers, 7½ by 10¼. The figures throughout are set in type sufficiently large to be easily read. The price is $2.00.

Industrial Furnace Technique

By A. Hermansen

A STUDY of this book shows that the author has investigated the history of the subject very thoroughly and has compiled a mass of valuable data which will be of great assistance to furnace builders as well as those wishing to study this subject.

Much of the data given appears to have been developed by the author, or his staff, and indicates that considerable time has been given to the work.

The chapters on regenerators and recuperators are especially valuable as they contain reliable, constructive data for the proper design of such units which has never been published before.

The author's discussion of the comparable time calorie and heat transfer quantity is of real interest as it explains rather clearly the reason why certain designs do not give satisfactory operation.

To a student interested in furnace operation, the chapters dealing with fuels and gases will be of inestimable value as they show an exceptional knowledge of and experience in the subject.

The formulae and tables on heat transmission are very complete and well arranged, covering as they do very fully heat by radiation as well as convection and the flow of gases at elevated temperatures.

Heat balance and determination of gas volume should be a simple matter for furnace builders if they study the chapters devoted to that subject.

Paragraphs dealing with powdered coal, no doubt will be amplified when the author has had opportunity to gather more complete data on this subject, especially as to American practice, and it is hoped that this will be done in the next edition.

As a whole this volume is the most complete treatise on furnace technique yet published and it merits the careful consideration of furnace designers and operators alike.

The book is cloth bound, 6¼ by 9½ and contains 293 pages. The price is $7.50.

Matthew Murray—Pioneer Engineer

Edited by E. Kilburn Scott

THIS is a most interesting little historical volume on the life and achievements of Matthew Murray who was believed to be born in Newcastle-on-Tyne in 1765. Murray was a prolific inventor in practically all fields of Mechanical Engineering. His most notable work was in connection with the design and development of steam engines, in which field he unquestionably earned the right to be called a pioneer.

A movement is now well under way to erect a memorial to Murray in Leeds where he spent most of his life and did his most conspicuous work. It was here that Murray built his famous "Round Foundry" as a part of the works of Fenton, Murray and Wood. Here also he built "Steam Hall" which is believed to have been the first steam-heated house.

In addition to various papers, articles and biographical sketches, the book contains a number of letters written by Murray and his contemporaries. These letters are an interesting commentary on the business methods of the time and would seem to indicate that since then we have made at least as great progress in business ethics as in engineering.

The proceeds from the sale of this book are contributed to the memorial fund. The price is $1.00.

NEW CATALOGS AND BULLETINS

Any of the following literature will be sent to you upon request. Address your request direct to the manufacturer and mention COMBUSTION Magazine

Boilers

The Keeler Double Duty Boiler is presented in an attractive new catalog. The name "Double Duty" was chosen as this boiler is offered for either power generation or steam heating service. The boiler is of all steel riveted joint construction. It is built for 100 or 125 lb. pressure and is offered to meet the demands for a boiler where service does not require the larger, more expensive, masonry set boilers. Dimension sheets are included to cover the full range of sizes available. 24 pages and cover, 8½ x 11—E. Keeler Company, Williamsport, Pa.

Deaerator

The Cochrane Self Contained Deaerator and Hot Water Generator is presented in Bulletin No. 686. In the Cochrane Deaerator, oxygen is eliminated from the water by a process comprising three simple steps. (1) The water is heated to the temperature at which water boils under the total pressure of the atmosphere which is in contact with the water. (2) The water is spread out by distribution over trays and is agitated to accelerate the liberation of gas. (3) The atmosphere in contact with the water is continually removed and replaced by pure steam, in order to carry away the liberated gases, through a vent. Details of design and application arrangements are well shown. 20 pages, 8½ x 11—The Cochrane Corporation, 17th Street and Allegheny Avenue, Philadelphia.

Draft Gage

The Ellison U-Tube Draft Gage, cover type, is presented in new Bulletin 13. This gage, or manometer, has a wide range of application for the direct reading of pressures, minus, plus or differential, of air and gases and for both stationary and portable use. A wide range of sizes is available, up to 20 in. of water with the oil type and up to 24 in. of mercury with the mercury type. 4 pages, 8½ x 11—Ellison Draft Gage Company, 214 West Kinzie Street, Chicago, Illinois.

Dustrap

Green's Dustrap is illustrated and described in Bulletins Nos. 159 and 161. This apparatus was developed primarily to catch the fly ash exhausted into the atmosphere from the stacks of power plants burning pulverized coal. The Dustrap is placed between the boiler outlet and the stack, preferably ahead of the induced draft fan. The gases pass through the trap horizontally and the dust is collected in hoppers at the bottom. The details of construction and performance figures are presented. 4 pages each, 8½ x 11—The Green Fuel Economizer Co., Beacon, N. Y.

Gages and Instruments

Defender Draft Gages and fittings are presented in a well illustrated catalog. Inclined type, and U-Tube gages or manometers are offered for a wide range of service. Special gages have been developed for use with various types of stokers, pulverized fuel firing, hand firing and oil firing. A range of scales is available for every condition of forced, induced or natural draft. Dimensions and list prices of all instruments are included. 24 pages, 8½ x 11—Defender Regulator Company, 308 South 8th Street, St. Louis, Mo.

Graphic Recording Instruments

Bulletin No. 130 discusses the applicability of various Esterline-Angus instruments to the graphic recording of conditions in steam plants and general industrial practice. The position of dampers, the setting of valves, the opening of gates, the height of liquids in tanks—all are easily and accurately recorded with graphic instruments. 4 pages, 8½ x 11—Esterline-Angus Company, Indianapolis, Indiana.

Gravity Storage Bins

At many plants, the problem of providing sufficient storage capacity for bulking materials such as coal, ashes, shavings, sawdust, etc., is a serious one. Neff and Fry Super-Concrete Stave Bins erected adjacent to tracks, provide an easy and economical solution. A handsome illustrated catalog describes various types of bins and presents much practical information on the general subject of storage. Many typical installations are shown and described. 64 pages, 8½ x 11—The Neff and Fry Company, Camden, Ohio.

Refractory Gun

The Quigley Refractory Gun is used with a premixed plastic refractory material composed of Hytempite, a refractory cement, mixed with crushed old firebrick. This plastic mixture when shot at high velocity, will stick to either a hot or cold wall owing to the force of its application, in cases where troweled or rammed-in applications might fail to hold. The gun has a wide field of use in the repair and maintenance of furnace linings, including hot patching and surface coating. 12 pages, 3½ x 6½—Quigley Furnace Specialties Co., 26 Cortland St., New York.

Steam Generating Units

A new brochure describes the three new pulverized coal fired, steam generating units recently installed at the East River Station, New York Edison Company. Each of these units was guaranteed to develop 800,000 lb. of steam per hour at 425 lb. pressure. Peak capacities up to 1,250,000 lb. per hour have actually been secured. The height from the bottom of the furnace to the top of the boilers is equivalent to that of an eight-story building. The aggregate length of the tubes in the three units is 69 miles and each furnace is capable of burning over 1000 tons of coal a day. 8 pages, 8½ x 11—Combustion Engineering Corporation, 200 Madison Avenue, New York.

Testing Laboratory

The facilities of the Pittsburgh Testing Laboratory are described in a well illustrated booklet. Complete chemical and physical laboratories are supplemented by an inspection and research service, which through an experience of nearly a half century, has touched almost every phase of industry. Fuel Analyses, Boiler Tests and Power Plant inspection are important phases of this company's work. 32 pages and cover, 8½ x 11—Pittsburgh Testing Laboratory, Pittsburgh, Pa.

Tube Expanders

Wiedeke Ideal Tube Expanders are illustrated and described in a new folder. These expanders, for power or hand use, are made entirely of a special steel, heat treated to withstand the enormous pressures created by the use of extra heavy tube sheets and the high speed, when power operated. The long combination taper and flaring rools expand and flare the tube or nipple in one operation. Cross section views of the expander show the details of design. 4 pages, 8½ x 11—Gustav Wiedeke Company, 1833 Richard Street, Dayton, Ohio.

Underfeed Stoker

The Detroit Underfeed Stoker is presented in a well prepared bulletin. This machine is built in a number of types and sizes which make it applicable to a wide range of conditions. The Detroit Junior Stoker is offered for apartment houses, office buildings, schools and similar applications. The Detroit Single Retort Stoker is recommended for boilers up to 300 hp. while the Detroit Multiple Retort Stokers are available for large boilers and high ratings. 8 pages, 8½ x 11—Detroit Stoker Company, General Motors Building, Detroit, Mich.

Water Gages

A recent bulletin describes the Keckley Water Gage which employs a unique design of packing gland. In the usual construction, a hexagon mit surrounds the gage glass. When this mit is turned down to tighten the packing gland, uneven strains are often produced and the mit may come into contact with the glass thus causing breakage. In the Keckley Gage two swing bolts are provided one on each side of the gland. These swing bolts engage the stuffing box bonnet which can be adjusted concentric with the glass. 6 pages, 8½ x 11—O. C. Keckley Company, 565 Washington Blvd., Chicago, Illinois.

NOTICE

Manufacturers are requested to send copies of their new catalogs and bulletins for review on this page. Address copies of your new literature

COMBUSTION

200 Madison Ave., New York

DRY STEAM *ALL THE TIME*

Regardless of

Boiler design,
Rate of driving boilers,
Boiler water concentration or
Method of feed water control

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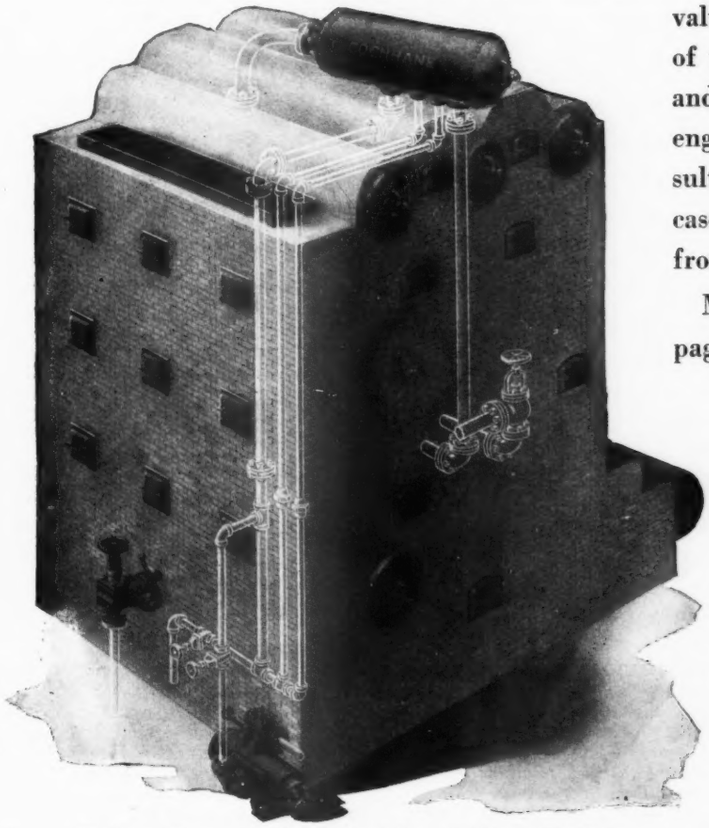
The benefits which result from complete protection to the superheater against scale and over-heating, from higher and more uniform superheat, from freedom of valves from sticking, from protection of turbines and engines against water and sludge or scale and from higher engine and turbine efficiency have resulted in complete satisfaction in all cases and in numerous repeat orders from large users.



Cochrane Steam Purifier drained by a Cochrane Discharger

May we send you a copy of our 32 page Bulletin on "PURIFICATION OF STEAM" in which the causes of wet steam, foaming and priming, steam liberating capacity of boilers, steam calorimetry, etc., are fully discussed?

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3160 North 17th Street
Philadelphia Pa.

PATENTS

Recently granted, and of Interest to our Readers.

Printed copies of Patents are furnished by the Patent Office at 10 cents each.
Address the Commissioner of Patents, Washington, D. C.

UNITED STATES PATENTS

Issued February 11, 1930

1,746,240. Boiler Construction. John J. Cain, Bayonne, N. J. Filed Sept. 1, 1926.

1,746,272. Heat-Conducting Tube. Thomas E. Murray, Brooklyn, N. Y.; Joseph Bradley Murray, Thomas E. Murray, Jr., and John F. Murray executors of said Thomas E. Murray, deceased. Filed June 18, 1924.

1,746,564. Heat Economizer. Louis D. Summers, Decatur, Ill., assignor to Leader Iron Works, Decatur, Ill. Filed Dec. 5, 1927.

1,746,673. Control System for Furnaces. El Roy L. Payne, Los Angeles, Calif. Filed Nov. 5, 1921, and renewed Apr. 14, 1923.

1,746,705. Blast Furnace. Heinrich Koppers, Essen Postfach, Germany. Filed Sept. 29, 1922, and renewed Mar. 1, 1927.

1,746,711. Boiler and the Like. Thomas E. Murray, New York, N. Y.; Joseph Bradley Murray, Thomas E. Murray, Jr., and John F. Murray executors of said Thomas E. Murray, deceased. Filed June 1, 1923.

1,746,982. Air Heater. Harry A. Atwater, Kansas City, Mo. Filed Nov. 14, 1927.

1,747,011. Superheater. Howard J. Kerr, El Mora, N. J., assignor to The Babcock & Wilcox Company, Bayonne, N. J., a Corporation of New Jersey. Filed Feb. 2, 1925.

1,747,067. Heat-Treating Furnace. Major E. Gates, Terra Cotta, Ill. Filed Oct. 6, 1926.

Issued February 18, 1930

1,747,193. Heating System. Ulrich A. Taddiken, Philadelphia, Pa., assignor to Westinghouse Electric & Manufacturing Company, a Corporation of Pennsylvania. Filed Nov. 30, 1927.

1,747,229. Apparatus for Improving Combustion in Fuel Burners. James G. Dudley, West Englewood, N. J. Filed Jan. 17, 1928.

1,747,333. Combustion Apparatus. Gustaf David Sundstrand, Rockford, Ill., assignor by mesne assignments, to Sundstrand Engineering Company, Rockford, Ill., a Corporation of Illinois. Filed Feb. 25, 1926.

1,747,421. Steam Generator. Charles Wesley Burroughs, Montreal, Quebec, Canada. Filed Feb. 16, 1927.

1,747,435. Soot-Removing System. Alexander Girtanner, New York, N. Y., and Joseph J. McNulta, Summit, N. J., assignors to Girtanner Engineering Corporation, New York, N. Y., a Corporation of New York. Filed Oct. 23, 1925.

1,747,612. Steam Boiler. Phillips Badenhausen, Philadelphia, Pa. Filed Aug. 30, 1927.

1,747,614. Retaining Means for Furnace-Wall Blocks. Ervin G. Bailey, Easton, and Ralph M. Hardgrove, Bethlehem, Pa., assignors to Fuller Lehigh Company, Fullerton, Pa., a Corporation of Delaware. Original application filed Oct. 20, 1927. Divided and this application filed Nov. 17, 1928.

1,747,671. Economizer. David S. Jacobus, Jersey City, N. J., assignor to The Babcock & Wilcox Company, Bayonne, N. J., a Corporation of New Jersey. Filed May 4, 1925.

1,747,676. Furnace and Process of Operating the Same. Howard J. Kerr, Westfield, N. J., assignor by mesne assignments, to Fuller Lehigh Company, a Corporation of Delaware. Filed Oct. 8, 1927.

1,747,822. Furnace - Construction. Raymond D. Foltz, East Orange, N. J., assignor to M. H. Detrick Company, Chicago, Ill., a Corporation of Illinois. Filed Jan. 7, 1924.

1,747,823. Furnace - Construction. Raymond D. Foltz, East Orange, N. J., assignor to M. H. Detrick Company, Chicago, Ill., a Corporation of Illinois. Filed May 7, 1924.

1,747,824. Furnace Wall Construction. Raymond D. Foltz, East Orange, N. J., assignor to M. H. Detrick Company, Chicago, Ill., a Corporation of Illinois. Filed Sept. 16, 1926.

1,747,855. Heating Furnace. William T. Bradley, St. Louis, Mich. Filed Nov. 23, 1927.

1,747,905. Refractories. Berry Marvel O'Harra, Westfield, and Edgar A. Slagle, Trenton, N. J., assignors to American Smelting and Refining Company, New York, N. Y., a Corporation of New Jersey. Filed June 12, 1928.

Issued February 25, 1930

1,748,070. Seal for Headers. William A. Jones, West New Brighton, N. Y., assignor to The Babcock & Wilcox Company, Bayonne, N. J., a Corporation of New Jersey. Filed Apr. 20, 1926.

1,748,113. Water-Tube Boiler. Alfred C. Danks, Cleveland, Ohio, and Kingsley L. Martin, Montclair, N. J. Filed Oct. 2, 1928.

1,748,137. Water-Tube Boiler. Kingsley L. Martin, Montclair, N. J., assignor of one-half to A. C. Danks, Cleveland, Ohio. Filed Feb. 20, 1928.

1,748,163. Feed-Water Heater. George M. Wolfe, Chanute, Kans. Filed Nov. 8, 1928.

1,748,815. Rotary Furnace. Clarence B. Wisner, Canton, Ohio, assignor, by mesne assignments, to Coal Process Corporation, New York, N. Y., a Corporation of Delaware. Filed Jan. 13, 1925.

1,748,920. Process of and Apparatus for Comminuting Material. Ray C. Newhouse, Milwaukee, Wis., assignor to Allis-Chalmers Manufacturing Company, Milwaukee, Wis., a Corporation of Delaware. Filed Feb. 23, 1928.

1,748,935. Steam Generator or Water Heater. Howard John Fountain, London, England, assignor of one-half to The Clarkson Thimble Tube Boiler Company, London, England. Filed Apr. 16, 1929, and in Great Britain Feb. 14, 1928.

Issued March 4, 1930

1,748,945. Boiler. Joseph F. Dickson and Robert M. Turner, Kewanee, Ill., assignors by mesne assignments, to Kewanee Boiler Company, Kewanee, Ill., a Corporation of Delaware. Filed Dec. 3, 1927.

1,749,116. Regenerative Heating Structure. Joseph Van Ackeren, Pittsburgh, Pa., assignor to The Koppers Company, Pittsburgh, Pa., a Corporation of Pennsylvania. Filed Oct. 5, 1923.

BRITISH PATENTS

Accepted January 16, 1930

306,145. A Method of Preventing Scale Deposits in Boilers. Alfred Heinrich, of 9, Riehlstrasse, Berlin-Charlottenburg, Germany.

309,996. Feed Water Supply Apparatus for High Pressure Steam Boilers. Louis Friedmann, Max Friedmann and Dr. Norbert Schopp, trading under the name of Firm Alex. Friedmann, of 6, Am Tabor, Vienna II, Austria.

323,824. Improvements in Apparatus for Firing Furnaces with Pulverized Fuel. Alfred John Elderton, Engineer Lieutenant Commander, Royal Navy, of "La Casita" Shepherds Lane, Dartford, Kent.

Accepted January 20, 1930

299,313. Improvements in Furnaces with Revolving Firegrates. Kai Petersen, of 4.G1, Kongevej, Copenhagen, Denmark.

324,081. Improvements in and relating to Composite Fuel. John Arthur Greene, of 12, Broadway, Westminster, S.W. 1, and Bindphast Products Limited, also of 12, Broadway.

324,111. Improvements in Steam Boilers. South Metropolitan Gas Company, of Great Britain, and Charles Claude Carpenter, both of 709, Old Kent Road, London, S.E. 15.

324,117. Improvements in or relating to Grading and Separating Apparatus. Frederick Whitfield Gee, of The Manor House, Pinner Middlesex.

Accepted January 23, 1930

309,091. Improvements in or relating to Steam Superheater Elements. Felix Houlet, of 16, bis, rue des Petits Pres, Epernay, Marne, France.

309,543. Improvements in Sieves for Sifting and Filtering Purposes. Rudolf Herrmann, trading as the firm Louis Hermann, of 33, Zwickauerstrasse, Dresden-A, Germany.

324,137. Improvements in Steam Condensing Apparatus. Sir George Croydon Marks, of 57 and 58, Lincoln's Inn Fields, London, W.C. 2.

324,145. Improvements in or relating to Furnace Bars for Forced Draught Furnaces. George Henry Collins, of 137, Ealing Road, Brentford, County of Middlesex.

324,157. Burner for Regenerative Furnaces. Heinrich Bangert, of 38, Brendamourstrasse, Dusseldorf-Oberkassel, Germany, and Gustav Huhn, of 27, Oberratherstrasse, Dusseldorf-Rath, Germany.

324,170. Improvements in Means for Automatically Controlling the Fuel Supply Valves of Steam Boilers. Neil Fletcher Michael, 91, Barlogan Avenue, Cardonald, Glasgow, and Alexander James Young, of 130, Katherine Avenue, Linthouse, Glasgow.

324,195. Improvements in or relating to Coke Ovens. William Diamond, of "La Noria" Marley Hill, County of Durham, England.

324,204. Improvements in Dust and like Separators. Matthews & Yates Limited, and Oswald Stott, both of Cyclone Works, Swinton, Manchester.

324,210. Improvements relating to Steam Generators. Daniel Adamson, of Hyde, County of Chester.

324,271. Improvements in or relating to Powdered Fuel Burners. Henry Edward Hazlehurst and Oliver Margetson, both of 22, Bloomsbury Street, London, W.C. 1.

324,304. Improvements in or relating to Soot Blowers. James Howden & Company Limited, of 195, Scotland Street, Glasgow, and James Howden Hume, of Caxton House, Westminster, London, S.W. 1.

A. S. M. E. Fiftieth Anniversary

The Fiftieth Anniversary of The American Society of Mechanical Engineers will be celebrated in April in Washington, and in New York. It will bring together the leading engineering authorities of the world, who will talk on the social and economic problems of their respective countries.

The celebration will begin April 5 in New York, where the delegates, members, and guests will register at the United Engineering Societies Building, 29 West 39th Street.

This will be followed by the unveiling of a tablet in the lobby of the building commemorative of the anniversary, and then at the offices of The American Machinist, Tenth Avenue and 36th Street, a program will be given to depict the preliminary meeting of the Society, on February 16, 1880.

The program will be continued at Stevens Institute, Hoboken, N. J., with a pageant commemorating the organization meeting in the auditorium of the Institute.

A welcoming dinner, under the auspices of the Metropolitan Section of the Society, will be given at 7:30 P. M. at the Hotel Roosevelt in New York. Charles M. Schwab, an honorary member and past-president of the Society, will be toastmaster. The speakers will be Charles M. Piez, president of the Society, James H. McGraw, Chairman of the Board of the McGraw-Hill Publishing Co., who will represent the engineering press, and Robert I. Rees, president of the Society for Promotion of Engineering Education, who will represent the field of engineering education.

Sunday morning at eleven o'clock there will be commemorative services at the Cathedral of St. John the Divine in New York City. That evening departure will be taken for Washington, D. C.

In Washington, April 7, at eleven o'clock a welcoming assembly will be held in the National Council Chamber of the U. S. Chamber of Commerce Building. Addresses will be given by representatives of the Government, the foreign delegates and various engineering and educational institutions.

Following an afternoon session devoted to the subject, "The Influence of Engineering upon Civilization," there will be a reception at the White House, while in the evening a reception will be given by the officers and council of the Society.

At noon Tuesday a luncheon will be held in honor of the founders of the Society, followed by the presentation of medals of distinction.

At a formal dinner on Tuesday evening at which Dr. W. F. Durand, past-president of the Society will be toastmaster, there will be addresses by the president of the American Society of Mechanical Engineers and by Dr. Robert A. Millikan, past-president of the American Association for the Advancement of Science.

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